



THE UNIVERSITY *of* EDINBURGH

This thesis has been submitted in fulfilment of the requirements for a postgraduate degree (e.g. PhD, MPhil, DClinPsychol) at the University of Edinburgh. Please note the following terms and conditions of use:

- This work is protected by copyright and other intellectual property rights, which are retained by the thesis author, unless otherwise stated.
- A copy can be downloaded for personal non-commercial research or study, without prior permission or charge.
- This thesis cannot be reproduced or quoted extensively from without first obtaining permission in writing from the author.
- The content must not be changed in any way or sold commercially in any format or medium without the formal permission of the author.
- When referring to this work, full bibliographic details including the author, title, awarding institution and date of the thesis must be given.

**DISENTANGLING IMITATION AND DYSPRAXIA
IN INDIVIDUALS WITH AUTISM**

Heidi Elizabeth Ham

Thesis presented for the degree of Doctor of Philosophy

University of Edinburgh

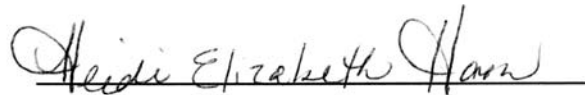
2009

DECLARATION

Disentangling Imitation and Dyspraxia in Individuals with Autism

I declare that this thesis is of my own composition, and that the material contained within describes my own work. It has not been submitted for any other degree or professional qualification.

All quotations have been distinguished by quotation marks and the sources of information acknowledged.

A handwritten signature in black ink, reading "Heidi Elizabeth Ham", written over a horizontal line.

Heidi Elizabeth Ham

April, 2009

ABSTRACT

Imitation deficits are well-documented in autism although the specific nature of these deficits is not completely understood. Researchers have attempted to account for imitation deficits within the context of cognitive theories of autism but these theories have not been successful in explaining all of the gestural disturbances reported in individuals with autism spectrum disorder (ASD). The types of gestural impairments along with error patterns observed in autism are similar to those reported in adult patients with limb apraxia. In this thesis, a neuropsychological account of apraxia was explored. A cognitive model of praxis processing that has been tested in adults with limb apraxia was adapted for a group of children with autism. An experimental battery of tasks was designed to assess the different levels of gestural processing following the cognitive model. The battery included seventeen different experimental tasks: nine tasks assessing the production of meaningful gestures across modalities (verbal, visual, tactile, and imitation); two tasks assessing the imitation of meaningless gestures; six tasks assessing gestural recognition and gesture comprehension.

The main aim of the thesis was to determine if the gestural performance patterns identified in individuals with autism could be more parsimoniously explained by disorders of praxis processing than by the traditional cognitive theories of autism. More specifically the aims were: (1) Determine if an ASD group differs from a group of typically developing controls in their ability to imitate meaningful and/or meaningless gestures, (2) Determine if deficits in gesture production are task dependent (transitive, intransitive, pantomimes), (3) Determine if group differences in gesture production are better accounted for by underlying cognitive deficits in visual motor (VMI), visual perceptual (VP), and working memory abilities (listening recall, (LR) digit recall (DR) and word list matching (WLM), (4) identify the specific patterns of gestural impairments using a single case approach to analysis using results of recognition, comprehension, production and imitation tasks across gesture types. Experiments testing gesture imitation and

gesture production across modalities employed a logistic regression approach to analysis which was designed to compare a group of individuals with autism to that of a typically developing control group. Five main findings emerged: (1) Individuals with autism performed more poorly in tasks of imitation and production across modalities than their typically developing peers; (2) Meaningful gesture imitation and production tasks were not performed equally, supporting the theory of task dependency; (3) The same cognitive variables predicting imitative success of meaningful gestures also predicted production success. An increase in visual perception and listening recall were associated with greater success; an increase in LR was also associated with greater success; (4) Different cognitive variables predicted imitation success of meaningless gestures. Listening recall was associated with increased success of hand imitation but not finger imitation. Finger matching was associated with higher performance of finger imitation but not hand imitation and this effect was slightly stronger in the TD group; (5) Results of the single case approach to analysis revealed that patterns of praxis processing were identified in individuals with autism that were similar to those of previously reported cases of limb apraxia. Ideational, ideomotor, and ideational with ideomotor praxic syndromes were all revealed. The results of this study confirm that the cognitive model of Cubelli and colleagues (2000) successfully predicted patterns of praxis processing in ASD thereby confirming that the deficit extends beyond imitation. Standard cognitive theories of autism were unable to accommodate all of the findings. The implications of these results and synthesis of dyspraxia and current autism theories are discussed.

CONTENTS

	Page
CHAPTER 1 – INTRODUCTION AND OVERVIEW OF THE THESIS	10
1.1 Introduction	10
1.1.1 Importance of Imitation in Development	10
1.1.2 Overview of Thesis	11
 CHAPTER 2 – A THEORETICAL ACCOUNT OF IMITATION IN AUTISM	 13
2.1 Autism as a Spectrum Disorder	13
2.1.1 Definition of Autism	13
2.1.2 Autism vs. Asperger Syndrome	14
2.1.3 Epidemiology	18
2.1.4 Gestural Impairments within <i>DSM-IV</i> Diagnosis	19
2.2 Theoretical Accounts of Imitation Deficits and Autism	21
2.2.1 Early Investigations of Imitation and Autism	21
2.2.2 Self-Identification Theory	24
2.2.3 Theory of Mind	28
2.2.4 Self-Other Mapping Hypothesis	30
2.2.5 Mirror Neuron Theory	32
2.2.6 Theory of Executive Dysfunction	36
2.3 A Neuropsychological Theoretical Account: Dyspraxia in ASD	39
2.3.1 Challenges in Interpreting Imitation Research in ASD	39
2.3.2 Implications for Imitation and Dyspraxia Research in ASD	41
 CHAPTER 3 – A NEUROPSYCHOLOGICAL APPROACH TO LIMB APRAXIA	 42
3.1 A Dyspraxic Account of Gestural Processing Deficits in Autism	42
3.1.1 Definition of Apraxia	42
3.1.2 Introduction to Dyspraxia	43
3.2 History of Apraxia	44

3.2.1 “Grandfather of Apraxia”	44
3.2.2 Ideational Apraxia	46
3.2.3 Ideomotor Apraxia	49
3.2.4 Gesture Types	50
3.3 History of Apraxia Theories	54
3.3.1 Liepmann’s Movement Formulas	54
3.3.2 Hemisphere Dominance	56
3.3.3. Two Stage Models	57
3.3.4 Disconnection Hypothesis of Apraxia	58
3.4 Development of Models of Praxis Processing	59
3.4.1 Representational Model	59
3.4.2 Cognitive Models of Praxis Processing of Rothi, Ochipa, and Heilman (1991)	60
3.5 Cognitive Model of Praxis Processing	63
3.5.1 Introduction	63
3.5.2 Cognitive Components of the Model	64
3.5.3 Possible Clinical Profiles of Apraxia Based on the Model	66
3.6 Testing the Cognitive Model of Apraxia	68
3.6.1 Meaningful and Meaningless Gesture Dissociation	69
3.6.2 List Effects	70
3.7 Goldenberg and Meaningless Gestures	71
3.8 Acquired Apraxia versus Developmental Apraxia	74
3.9 History of Developmental Dyspraxia	74
3.10 The Need to Apply Adult Models of Apraxia to Developmental Dyspraxia Paediatric Populations	76
3.11 ‘Clues’ for Neuropsychological Evidence: of Dyspraxia in Autism	78
3.11.1 Dyspraxia ‘Clues’ from Studies of Meaningless Gestures in Autism	79
3.11.2 Dyspraxia ‘Clues’ from Meaningless and Meaningful Gestures	87
3.11.3 Dyspraxia ‘Clues’ from Pantomimes	89
3.11.4 Dyspraxia ‘Clues’ from Pantomimes and Intransitive Gestures	93
3.12 Summary of Studies	100

CHAPTER 4 – METHODOLOGY AND DESIGN OF BATTERY OF TASKS FOR IMITATION AND DYSPRAXIA	101
4.1 Rationale for the Assessment of Apraxia in Autism	101
4.2 Methods	103
4.2.1 Participants	103
4.2.2 Preassessment Measures	105
4.3 Apraxia Assessment	107
4.3.1 Two Tasks Assessing Meaningless Gestures	110
4.3.2 Three Tasks Assessing Recognition of Meaningful Gestures	113
4.3.3 Three Tasks Taxing the Comprehension of Meaningful Gestures	119
4.3.4 Three Tasks Assessing the Production of Gestures	123
4.3.5 Three Tasks Assessing the Imitation of Meaningful Gestures	128
 CHAPTER 5 – IMITATION OF MEANINGLESS AND MEANINGFUL GESTURES	 134
5.1 Meaningless Gesture Imitation	134
5.1.1 Introduction	134
5.1.2 Method Review	137
5.1.3 Results of Meaningless Gestures	139
5.1.4 Discussion	149
5.2 Imitation of Meaningful Gestures	152
5.2.1. Introduction	152
5.2.2 Method Review	156
5.2.3 Results of Meaningful Gestures	158
5.2.4 Discussion	170
 CHAPTER 6 – PRODUCTION OF MEANINGFUL GESTURES ACROSS MULTIPLE MODALITIES	 178
6.1 Meaningful Gesture Production	178
6.1.1 Introduction	178
6.1.2 Method Review	180
6.1.3 Results of Meaningful Gestures	181

6.1.4 Discussion	191
------------------	-----

CHAPTER 7 – ANALYSIS OF PRAXIS PROCESSING IN INDIVIDUALS WITH AUTISM

7.1 Testing a Cognitive Model of Praxis Processing	202
7.1.1 Introduction	202
7.1.2 Method Review	203
7.1.3 Results of Individual Tasks	206
7.2 A Single Multiple-Case Approach to Analysis	211
7.2.1 Deficit at the Level of the Input Lexicon	212
7.2.2 Deficit at the Level of the Action Semantic	220
7.2.3 Deficit at the Level of the Action Output Lexicon	223
7.2.4 Deficit at the Level of the Visuo-Motor Conversion Mechanism	225
7.2.5 Patterns Not Explained by the Cognitive Model	226
7.2.6 Discussion	228
7.3 Overall Conclusions	230

CHAPTER 8 – APRAXIA BATTERY CONCLUSIONS

8.1 Applications of the Current Research	233
8.1.1 Original Contributions of the Research	233
8.1.2 Future Extensions of the Research	235
8.1.3 Clinical and Therapeutic Implications of the Findings	237
8.1.4 Limitations of the Tasks and Methodology	238
8.2 Relationship of the Findings to Models of Limb Apraxia	240
8.2.1 Theoretical Implications of the Findings	240
8.2.2 Possible Adaptation to the Cognitive Model	244
8.3 Applying Models Based on Adult Acquired Disorders to Developmental Disorders	245

ACKNOWLEDGEMENTS

REFERENCES	257
-------------------	------------

APPENDICES	280
-------------------	------------

Appendix A. Apraxia Battery Clinical Forms	280
Appendix B. Pictorial Stimuli Administered in Experimental Task 4	297
Appendix C. Pictorial Stimuli Administered in Experimental Task 5	303
Appendix D. Pictorial Stimuli Administered in Experimental Task 6	309
Appendix E. Pictorial Stimuli Administered in Experimental Tasks 16 and 17	320
Appendix F. Pictorial Stimuli Administered in Experimental Tasks 18 and 19	322
Appendix G. Journal Article	330

CHAPTER 1

INTRODUCTION AND OVERVIEW OF THE THESIS

1.1 INTRODUCTION

1.1.1 Importance of Imitation in Development

As the number of individuals worldwide diagnosed with Autism Spectrum Disorder increases every year (National Autistic Society, 2007; Center for Disease Control, 2007), researchers are striving to meet the needs of this growing population. Recent trends in the field of autism require cross-disciplinary research and extensive collaboration on multiple levels, integrating many areas including developmental psychology, neuropsychology and psycholinguistics. A major challenge in conducting research in autism is the heterogeneity of the population; ranging from the lower-functioning nonverbal individuals, some of whom never acquire functional speech (Lord & Paul, 1997; Lord, Risi, & Pickles, 2004), to high-functioning autistic individuals.

Autism is a spectrum disorder occurring along a continuum of severity, and the differences in functional outcomes among autistic individuals are striking. Therefore, research pinpointing significant predictors of long term success and positive functional outcomes in autistic individuals is essential. Despite the heterogeneity, however, core deficits are evident in individuals across the spectrum, and identifying a possible deficit that may be implicated in the sequelae of social interaction and communicative impairments would pose a logical starting point for empirical research.

The ability to imitate is an early and important developmental milestone that continues throughout the lifespan (Metzloff & Moore, 1977, 1983), and is believed to provide the foundation for social identification, perspective taking, and

emotional connectedness (Metzloff & Gopnick, 1993; Meltzoff & Decety, 2003). Because imitation is a critical developmental milestone, it is of special interest to research in developmental disabilities, particularly autism spectrum disorder. Charman et al. (2000) suggested that the study of imitation is necessary to inform our understanding of atypical development in autism, specially the development of social communication, to determine the core skills that impact the long-term outcome of individuals on the autism spectrum. Imitation performance may predict gains in expressive or receptive language similar to tasks of joint attention (Mundy, Sigman, & Kasari, 1990) in autistic children and it appears that immediate vocal and gestural imitation in infants is positively correlated with expressive language development in the second year of life (Masur & Rodemaker, 1999). These results have led researchers to suggest that “joint attention and immediate imitation are important starter set skills that set the stage for social and communicative exchanges in which language can develop” (Toth et al., 2006, p.994). Following these findings, the inadequate development of these “starter set skills” including gestural imitation, is an important focus in autism research.

In parallel, the underlying motoric disturbances in autism are a critical area of imitation research in children with developmental disorders, including ASD. Many children with ASD demonstrate difficulty in imitating manual gestures, even when they are taught signs (Page & Boucher, 1998). Seal and Bonvillian (1997) showed that measures of dyspraxia and fine motor coordination were positively correlated with the production and vocabulary size of manual signs in children with autism. However the question remains as to the relationship between imitation and dyspraxia and the underlying cognitive mechanisms predicting gestural performance in ASD.

1.1.2 Overview of Thesis

Chapter 1 provides an introduction to the importance of imitation in development along with an overview of the current thesis. The second chapter describes the

theoretical explanations of the imitation deficit in autism, discussing their origins as well as providing examples of supporting findings in individuals with ASD. A number of challenges in the interpretation of imitation studies are presented along with an introduction to a neuropsychological explanation of dyspraxia. The final section reviews important representative samples of imitation experiments that provide evidence of a dyspraxic deficit in individuals with autism.

Chapter 3 reviews the literature of praxis processing in patients with limb apraxia. Accounts of the development of cognitive models of apraxia are outlined along with case reports supporting the cognitive model. The comparison of the literature in developmental dyspraxia and acquired apraxia will be discussed along with the rationale for the use of adult models in paediatric populations. Adaptation of an apraxia battery for adults to the autism population was reviewed. Chapter 4 presents the methodology of the experimental battery of tasks. Chapters 5 and 6 present the group findings of the imitation and production experiments respectively. Chapter 7, the final chapter, provides results of the single-multiple case approach to analysis of praxis processing. This approach follows studies in adult neuropsychology and the benefits of this analysis are highlighted along with the patterns of praxis processing identified in individuals with autism. The final section provides an overview of the significant findings along with suggestions for synthesis of imitation and dyspraxia within the context of the cognitive theories of autism.

CHAPTER 2

A THEORETICAL ACCOUNT OF IMITATION IN AUTISM

2.1 AUTISM AS A SPECTRUM DISORDER

2.1.1 Definition of Autism

Autism is a complex neurodevelopmental disorder characterised by a ‘triad of impairments’ in the areas of social interaction; language and communication; and restrictive, repetitive, and stereotypical patterns of behavior (American Psychiatric Society, *DSM –IV*, 1994). The *DSM-IV* diagnostic criteria for autism (1994) was the end result of an international collaboration of both research and clinical institutions across twenty-one different sites, and included the evaluation of almost 1,000 cases of autism (Volkmar, Klin, & Cohen, 1997). In this new classification, autistic disorder was included under the general category of PDD or Pervasive Developmental Disorders. Five categories are currently listed under the PDD umbrella: Autistic Disorder (AD); Asperger Syndrome (AS); Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS); Rett Syndrome; and Childhood Disintegrative Disorder. For accurate diagnosis of autism (*DSM-IV* 299.0), a total of at least six items from the three major groups are required; two of the criteria for social interaction (group 1), one from impaired communication (group 2) and one from restricted interests or repetitive behaviours (group 3). Also, “a delay or abnormal functioning in at least one of the following areas, with onset prior to age 3 years: (1) social interaction, (2) language as used in social communication, or (3) symbolic or imaginative play” (*DSM-IV* cited in Volkmar et al., 1997, p. 28) must be documented. The World Health Organisation’s (WHO) 10th Edition of the *International Classification of Diseases (ICD-10)* is the second major classification system of diagnosis. The *ICD-10* and the *DSM-IV* diagnostic classification systems are closely related according to ‘legal convention’ (Volkmar et al., 1997). However, there are differences

between the two systems (Volkmar & Schwab-Stone, 1996). For example, the *ICD-10* has two separate classifications for research and clinical purposes; therefore the research descriptions are much more detailed than the *DSM-IV* version (Volkmar et al., 1997). Although a distinction between low and high functioning individuals is not addressed in the DSM-IV, typically individuals with IQ scores below 70 are considered low-functioning along with other types of biological causes (Rapin, 1999), and high-functioning autism (HFA) has been defined as autism with normal intelligence (Ghaziuddin & Mountain-Kimchi, 2004). Further complicating the issue, ASD has often been used to describe individuals with normal intelligence as having high-functioning autism (Volkmar, State, & Klin, 2009). Thus, there appears to be some confusion as to how to define and distinguish three different categories – autism without mental retardation, Asperger Syndrome, and PDD-NOS (Volkmar, State, & Klin, 2009).

2.1.2 Autism vs. Asperger Syndrome

Autism can hardly be discussed without first acknowledging two important researchers credited for the initial publications of the identification and description of Autism and Asperger Syndrome; Leo Kanner and Hans Asperger respectively.

Kanner published his seminal paper, ‘Autistic disturbance of affective contact’ in the journal, *Nervous Child*, in 1943. He described eleven case studies of children who had been unable to establish and maintain affective relationships since birth. He reported that individual differences existed in the manifestation of the various characteristics and suggested that the disorder comprised a syndrome. Unfortunately, the use of the word ‘autism’ created confusion in the early days of the diagnosis because this was a term that was borrowed from schizophrenia research. Although Kanner was trying to emphasise that autistic children were withdrawn into their own worlds, the term had different connotations in schizophrenia research of “self-centered thinking that led to autistic withdrawal

into a private fantasy world” (Volkmar et al., 1997, p. 10). The overlap of the use of the term ‘autism’, in addition to Kanner’s belief that stress of parental-child relations played a role in the development of the disorder, clouded the perception of autism for many years (Rinehart, Bradshaw, Brereton, & Tonge, 2002; Volkmar et al., 1997).

In 1944, a year after Leo Kanner reported his findings, Hans Asperger published his seminal paper, “Autistic Psychopathy in Childhood” (Asperger, 1944, cit. in Mayes, Calhoun, & Crites, 2001) where he described case studies and characteristics of children demonstrating marked impairments in social interaction (Frith 1991 cit. in Klin & Volkmar, 1997). Asperger referred to the disorder as *Autistischen Psychopathen im Kindesalter*, translated as autistic personality disorders in children (Asperger, 1944, cit. in Klin & Volkmar, 1997).

In addition to the difficulties of social integration, Hans Asperger described eight observed ‘behavioural clusters’, including: Impairment in nonverbal communication; idiosyncrasies in verbal communication; social adaptation and special interests; intellectualisation of affect; clumsiness and poor body awareness; conduct problems; age of onset; and familiar and gender patterns (Asperger, 1944 cit. in Klin & Volkmar, 1997). Whilst the development of speech and language appeared to be less affected in the cases of Asperger’s account, motor deficits were readily apparent (Klin & Volkmar, 1997). Although Asperger syndrome is often referred to as a mild form of autism, Hans Asperger did not believe that Asperger syndrome was merely a ‘milder variant’ of autism and he argued that it was a distinct disorder that could stand on its own. Surprisingly, a separate diagnosis for Asperger Syndrome was not included in the *ISD-10* until 1992 and in the *DSM-IV* classification until 1994.

Asperger’s work was virtually unknown outside of Germany until 1981 when Lorna Wing published her account and description of 35 cases of individuals with Asperger Syndrome (Mayes et al., 2002; Wing, 1981). Out of the 35 patients, nineteen demonstrated patterns similar to Asperger’s original description and

fifteen presented with a different pattern of the onset of symptoms, and a different clinical history (Klin & Volkmar, 1997). Wing described the following characteristics of AS as shown within the first two years of life of a patient.

- “A lack of normal interest and pleasure in other people is evident from babyhood.
- Babbling may be limited in quantity and quality.
- Sharing of interests and activities may be very reduced. There may be a lack of intense drive to communicate verbally and nonverbally with others.
- Speech acquisition may be delayed, and speech content may be very impoverished, reflecting primarily utterances copied inappropriately from other people or learned rote from books.
- Asperger’s ‘talking before walking’ assertion does not apply to a great number of cases.
- Imaginative pretend play does not occur or is confined to one or two rigid themes enacted repetitively without variation.”

Klin & Volkmar (1997, p. 96).

To date, controversy still exists between accurately diagnosing individuals with autism vs. individuals with Asperger Syndrome (Ghaziuddin, 2008; Rinehart, Bradshaw, Brereton, & Tonge, 2002). Miller and Ozonoff (1997) reevaluated the original cases of Hans Asperger and reported that by definition, those same cases would only meet *DSM-IV* criteria for autism, but not Asperger Syndrome. Also, the lines are blurred between High-Functioning Autism and Asperger Syndrome. In 1998, Wing denied that there was any distinction between the two classifications and that High-Functioning Autism and Asperger Syndrome were synonymous (Wing, 1998 cit. in Mayes, Calhoun, & Crites, 2001).

Language development and IQ have traditionally been considered as characteristics accurately distinguishing an Asperger diagnosis (Ghaziuddin & Gerstein, 1996; Rinehart et al., 2002) from a diagnosis of autism; specifically the *lack* of a documented delay in cognitive and speech and language development. The *DSM-IV* definition of Asperger syndrome uses the same criteria for social impairment as autism and does not include communication impairment as one of the symptoms of Asperger syndrome (Mayes et al., 2002). As a result, the *DSM-IV* definition has not been accepted by all researchers (Klin & Volkmer, 1997). Currently, it appears that the definition of Asperger Syndrome is still under debate. Asperger's original report discussed areas of both commonalities and differences from autism; including unimpaired language development, high-rate of family member trait similarities, and restricted or fact-based interests (Volkmar, State, & Klin, 2009).

The *ICD-10* (WHO, 1992) also excluded the language cluster for diagnosis of Asperger Syndrome, “indicating the absence of severe language impairment in AS while sidestepping an attempt to define the peculiarities typical of verbal communication in AS” (Klin & Volkmar, 1997; p. 99). Interestingly, in the *DSM-IV* definition of Asperger syndrome, “Neither the *ICD-10* nor the *DSM-IV* definition explicitly requires a highly circumscribed interest or a motor delay, both of which would appear more typical of cases that correspond most closely to Asperger’s original definition” (Volkmar, Klin, & Cohen, p. 28). Subsequently, according to the *DSM-IV* diagnostic system, it is not possible for an individual to be diagnosed with autism and Asperger Syndrome simultaneously (Ghaziuddin, 2008).

Clinical features have been investigated to determine if they possibly differentiate individuals with autism from individuals with Asperger Syndrome. Avenues under exploration include pedantic speech (Ghaziuddin & Gerstein, 1996); motor clumsiness (Ghaziuddin & Butler, 1998); and executive functioning (Verté, Geurts, Roeyers, Oosterlaan, & Sergeant, 2006). Also, differences between verbal IQ (VIQ) and performance IQ (PIQ) have also been documented in

individuals with Asperger Syndrome. Whereas individuals with high-functioning autism have been reported to score higher in tests of performance IQ such as the block design task, the opposite profile has been found in AS (Rutter, 1978 cit. in Ghaziuddin & Mountain-Kimchi, 2004). In one study, fifty percent of individuals with AS performed higher on tests of VIQ than in tests measuring PIQ (Ozonoff, South, & Miller, 2000). In another report, 82% of an AS group scored higher in tests of VIQ than PIQ (Ghaziuddin & Mountain-Kimchi, 2004).

However, it may be a qualitative description of the observed social interaction in individuals with AS that provides additional insight into the nature of the social impairment. It may be that these individuals are not aloof as previously described, but demonstrate pragmatic language impairment and attempt social interaction without understanding the social norms (Klin, Paul, Schultz, & Volkmar, 2005; Twachtman-Cullen, 2001).

2.1.3 Epidemiology

In addition to the diagnostic debate, the study of epidemiology in autism is also confusing, with various studies publishing conflicting findings of incidence and prevalence rates. Incidence is defined as the number of new cases over a specific time and it is used in diseases and disorders with known origins; however developmental disorders are often difficult to measure because their onset age differs from their age of diagnosis (Medical Research Council, 2001). Prevalence, on the other hand, looks at one period of time or a span of time and then measures the number of known cases (Medical Research Council, 2001).

Moreover, the debate continues as to whether or not the incidence of autism spectrum disorders is on the rise, or if the increase is a result of better diagnosis and increased parental and community awareness. The best estimates to use to determine the total prevalence of ASD in the UK are the ones that include the whole autism spectrum (National Autistic Society, 2004). The National Autistic

Society reports that autism is “touching the lives of 500,000 families throughout the UK” (National Autistic Society, 2004). According to recent estimates, one in 100 children is reportedly affected by the disability in the UK alone (Baird, Simonoff, Pickles, Chandler, Loucas, Meldrum, & Charman, 2006).

In 2000, the average ASD prevalence rate was 6.7 per 1,000 children (at 6 different sites) and in 2002, 6.6 per 1,000 children (at 14 different sites). In 2004, the CDC (Centers for Disease Control) found that the prevalence rates were between 2 and 6 per 1,000 children. Therefore, using the higher rate, it was reported that up to 1 in 166 children are on the autism spectrum. In 2007, the Autism and Developmental Disabilities Monitoring Network (part of the CDC) reported that the figure had risen to 1 in 150 children (ADDM, 2007). More than 1.5 million Americans are considered to be on the autism spectrum (Center for Disease Control Prevention, 2007).

2.1.4 Gestural Impairments within *DSM-IV* Diagnosis

Autism is a developmental disability that affects not only the individual, but the entire family, and its impact on the family unit cannot be underestimated (National Research Council, 2001). One of the greatest sources of communication difficulty families and caregivers face when dealing with preverbal autistic children is that they do not compensate for their language deficit through the use of functional gestures, failing to spontaneously use conventional gestures to make their needs known (Wetherby, Prizant, & Hutchinson, 1998; Woods & Wetherby, 2003).

Since the time of Kanner, gestural impairments in autism have been reported. Kanner (1943) published this description of a child from his original research, “Her expression was blank, though not unintelligent, and there was no communicative gestures” (p. 240). Curcio (1978) reported that children with autism did not use any pointing or showing gestures and stated that this performance was striking

when compared to typically developing children. Significant impairments in the use of functional and symbolic communicative gestures as well as conventional gestures (e.g., giving and showing) have been documented (Wetherby et al., 1998; Wetherby, Prizant, & Schuler, 2000; Woods & Wetherby, 2003). Individuals with autism typically use 'primitive' presymbolic hand over hand gestures to communicate basic needs, (i.e., placing another persons hand on a doorknob to open the door, or pushing or pulling another person to a desired location: Wetherby & Prutting, 1984; Wetherby et al., 2000; Woods & Wetherby, 2003). In the context of therapeutic intervention, communicative gestures are often taught using imitation, typically immediate imitation (Smith & Bryson, 1994).

Subsequently, gesture impairment is an important component within the *DSM-IV* criteria for autistic disorder. Two items under the major heading of social interaction (Category (a) below) are required and one criterion from communication (Category (b) below). One example is given for each category.

(a) Marked impairment in the use of multiple nonverbal behaviours such as eye-to-eye gaze, facial expression, body postures, and *gestures* to regulate social interaction and, (b) delay in, or total lack of, the development of spoken language (not accompanied by an attempt to compensate through alternative modes of communication such as gestures or mime: American Psychiatric Society, *DSM –IV*, 1994).

The aim of the present thesis is to examine the production and imitation of gesture in autism in detail. In the following section, relevant studies of gestural imitation and production will be discussed highlighting the most frequently cited theoretical accounts of imitation deficits in autism.

2.2 THEORETICAL ACCOUNTS OF IMITATION DEFICITS IN AUTISM

2.2.1 Early Investigations of Imitation and Autism

The study of imitation has intrigued scientists for over a hundred years. One of the earliest published works in imitation in infancy reported findings of a nine month old infant that imitated hand closing, lip movements, and object use (Baldwin, 1892, p.15). Contemporary definitions of neonatal imitation define imitation as “various facial, hand, and finger movements, and vocalisations made by a young infant in a laboratory environment shortly after an experimenter has modelled the same behaviour to the infant” (Nagy & Molnar, 2004, p.55). Mounting evidence supporting successful neonatal imitation has been published over the course of several decades and the results are now well established in the field of developmental psychology.

Not only is imitation an important milestone in typical development, but an imitation deficit is now considered to be an important risk factor when assessing siblings of autistic children (Zwaigenbaum et al., 2005) and imitation performance is often evaluated in tests of early functional and symbolic communication (Wetherby, Woods, Allen, Cleary, Dickinson, & Lord, 2004). Charman et al. (2000) suggest that the study of imitation is necessary to inform our understanding of atypical development in autism, specifically development of social communication, to further explore the core skills that impact long-term outcome of individuals on the autism spectrum. Stone, Ousley, and Littleford (1997) stated that “the development of motor imitation in autism is less well understood” than in typically developing children (Stone et al., 1997, p. 476) and encouraged further testing in individuals with autism.

Many of the early imitation studies in autism were founded in a developmental approach highlighting the importance of imitation in the context of sensorimotor development and therefore were not solely imitation studies. (Smith & Bryson, 1994; Abrahamsen & Mitchell, 1990; Curcio, 1978; Dawson & Adams, 1984;

Wetherby & Prutting, 1984). The following studies all emphasise an imitation deficit in autism and highlight dissociations in performance between tests of imitation and other types of developmental tests.

Historically, vocal and gestural imitation tests were often administered within the context of developmental assessments such as The Uzgiris and Hunt (1975) Scales of Sensorimotor Development. The Uzgiris and Hunt (or Uzgiris-Hunt Scales) is an assessment of sensorimotor skills including object permanence, means-ends, causality, the construction of objects in space, object-related schemes, and vocal and gestural imitation (Abrahamsen & Mitchell, 1990). The imitation component of the test included eight different tasks measuring gestural imitation in a hierarchical fashion. The gestural imitation trials began with 'simple familiar gestures' that typically developing children pass at 7 months (e.g., clapping hands) and moved to unfamiliar 'visible', and 'invisible' gestures (one that cannot be viewed from one's own point of view) passed by 20 months of age. Therefore, the comparison of early imitation findings must be considered within the context of the gestural tasks of the Uzgiris-Hunt Scales and imitation deficits in individuals with autism have been reported in the tasks of familiar and unfamiliar visible and invisible gestures (Curcio, 1978; Dawson & Adams, 1984; Sigman & Ungerer, 1984; Wetherby & Prutting, 1984). However, opposite findings have also been published using the same evaluation (Charman & Baron Cohen, 1994; Morgan, Cutrer, Coplin, & Rodrigue, 1989).

Because many of the early imitation studies were included within the assessment of sensorimotor development, the comparison between imitation and levels of sensorimotor functioning were often included in the interpretation of findings. Dawson and Adams (1984) tested 15 autistic children, aged 4-6 years. The goals were to determine the level of sensorimotor functioning as well as to determine if imitation was a 'selective deficit' in autism. The authors predicted that the level of imitation on the Uzgiris-Hunt scales would relate to social behaviours in play settings (e.g., looking, smiling). The authors did find a relationship but it was not revealed if the vocal and gestural scores were combined and this is important

because vocal imitation and gestural imitation may affect the development of social behaviours in play skills differently. Other studies have identified associations between vocal imitation but not gestural imitation to the development of language (Masur & Rodemaker, 1999; Wetherby & Prutting, 1984).

Sigman and Ungerer (1984) tested 16 autistic children and compared them to two different groups; one typically developing and one with cognitive delay. Vocal and gestural imitation tests of the Uzgiris and Hunt (1975) Scale were used as well as an assessment of play in both structured and unstructured settings. The vocal and gestural imitation scores were lower in the autistic group than in the other two comparison groups in the testing. Also, a significant association between receptive language and verbal and gestural imitation was reported. A unique deficit in imitation and symbolic abilities in children with autism was also documented in this study.

Wetherby & Prutting (1984) administered a cognitive-social battery of tasks assessing communicative competence and tested four autistic children. They compared the autistic children to four children with matched language levels. The authors administered gestural and vocal imitation tasks using the criteria from the Uzgiris and Hunt (1975) Scale. The gestural imitation task contained four 'imitation schemes'; two were unfamiliar gestures (meaningless) and two were familiar action sequences (meaningful). Results of the cognitive-social assessment revealed an uneven pattern of development for the autistic children whereas the typically developing group demonstrated a synchronous developmental pattern. The authors suggested that gestural imitation may be important for the development of referential sign language. Further, they suggested that because of the timing of development of component skills, this uneven pattern may affect qualitative differences in development in autistic children.

Abrahamsen & Mitchell (1990) tested ten children with autism, 4 children used verbal speech to communicate and were described as verbal and 6 children did not communicate through verbal means and were termed nonverbal. The

children were assessed in tasks of vocal and gestural imitation. The authors suggested that imitation may be important for the development of words and signs necessary for the development of vocal and gestural imitation respectively. They also reported an association between vocal imitation and spoken language. One important finding was that ability to imitate appeared to differentiate the verbal from the nonverbal autistic child. This is an important finding because many suggest that imitation provides the cornerstone to future developmental skills in joint attention, symbolic play, verbal and non-verbal language skills, and the development of a theory of mind (Rogers & Pennington, 1991). Abrahamsen and Mitchell (1990) stressed the importance of a detailed examination of imitation skills in autism.

While these early imitation studies provided an important step to the beginning of documenting an imitation deficit in autism, they did not address the nature of the underlying imitation deficit in individuals with autism (Smith & Bryson, 1994). In addition to symbolic deficits within sensorimotor skills, a range of theoretical accounts of imitative deficits in autism have been considered. Affective theories including the theory of Self-Identification (Hobson & Lee, 1999) and cognitive theories including the Self-Other Mapping (Rogers & Pennington, 1991); Mirror Neuron (Oberman & Ramachandran, 2007; Williams, Whiten, Suddendorf, & Perrett, 2001), and Executive Functioning hypotheses have all been explored. These are discussed below.

2.2.2 Self-Identification Theory

Hobson and colleagues (1999; 2002; 2005) drew upon numerous studies of infant development and parent-child interactions to formulate the Self-Identification theory, an intriguing hypothesis grounded in developmental psychopathology highlighting the importance of intersubjectivity or “mutually coordinated mental states” (Hobson & Lee, 1999; Hobson, 2002, p. 270; Hobson & Meyer, 2005). Hobson (2002) suggested that the “clinical features of autism develop because of a

disruption in the system of child-in-relation to others” and that this lack of development, in turn, affects mental development (Hobson, 2002, p. 183). Together, the interactions between the caregiver and the infant become a ‘motive force’ and dramatically affect the development of the child. Consequently, intersubjectivity is necessary for the development of future skills in joint attention, language and cognition (Hobson & Hobson, 2007).

In other words, at the core of this account is a primary affective disorder that disrupts the child’s ability to connect with others and impedes the development of self-other awareness. The theory also addresses the imitation impairments often observed in autism. According to this account, deficits in emotional sharing and intersubjectivity affect the development of self-other awareness, and the difficulties in self-other awareness, in turn, affect motor imitation. Hobson (2002) argued that before an infant demonstrates the ability to imitate another’s actions, he initially must connect to and perceive that person as an entity. Therefore, a primary deficit in affect, from this point of view, would impair a child’s ability to imitate, secondary to the lack of the individual’s ability to emotionally connect with the examiner and the inability to take another perspective related to another’s psychological state (Hobson, 2002).

The following studies discuss ‘self-other’ and the role of emotional connectedness in imitation. In 1999, Hobson and Lee published their imitation findings measuring an aspect of imitation that had not previously been considered: Style. Based on their hypothesis that individuals with autism show a specific disability in the *identification of the attitudes of others* and not necessarily the imitation of actions, they designed an experiment tapping into this unique aspect of intersubjectivity (Hobson & Lee, 1999). Although the authors stated that defining the testable concept of ‘style’ was challenging; they explained that it was most closely related to the ‘how’ of the imitation task and not the ‘what’ of the task, thereby differentiating it from goal-directed action imitation (Hobson & Lee, 1999). In this case, the style was measured in terms of ‘harsh’ and ‘gentle’ qualities of the imitation trial. In addition to the style, Hobson & Lee (1999) also evaluated the

manner of imitation; a measurement capturing self-orientation or *how* the participant imitated an action in relationship and orientation of their own body. The authors found that only 2 out of 16 autism participants imitated the manner and the style of imitation. See Fig. 2.1 for an example of an experiment for the imitation of a pipe rack and a stick testing the 'style' of imitation.



Figure 2.1. Pipe rack and stick imitation test. Hobson, R.P. and Lee, J. (1999) Imitation and Identification in Autism. *Journal of Child Psychology and Psychiatry*, 40 p. 649-659.

Hobson (2002) suggested that a primary deficit in affect would impair a child's ability to imitate secondary to their inability to emotionally connect with the examiner and the inability to take another perspective and relate to another's psychological state.

Meyer and Hobson (2004) conducted a follow-up study to confirm previous findings that autistic children failed to imitate the self-orientation component of the imitation task (Hobson & Lee, 1999). Results, after testing four different actions on objects, indicated that the autistic participants were less likely to imitate the orientation of self and other as compared with those children in the typically developing control group. Only 3 out of 16 children in the ASD group imitated the self-other orientation aspect of the action, and 5 of the autistic children performed reversal errors. The authors argued that these findings supported their hypothesis that an impairment in a "biologically grounded mechanism" essential for supporting the propensity to 'identify' or connect with another individual to the point of assimilating another's orientation was at the core

of the imitation deficits in autism (Hobson & Meyer, 2005, p. 482).

An exploration of self-referential imitation was undertaken to explore whether children with autism would point to their own bodies when communicating information about location on another person's body (Hobson & Meyer, 2005). The first task was designed to provide an opportunity for the participants to communicate body position using gesture. A sticker was included in the task which required the participant to point to the location where they wanted the tester to place the sticker. The experimental hypothesis followed the identification theory in predicting that the children with autism would not point to their own bodies to communicate necessary location information but would point to the tester's body instead. Indeed, a majority of the autistic participants pointed to the tester's body and not to themselves. In the second task, the prompt required the tester to point to a location on the *tester's* own body to cue the participants to place the sticker on their own body. Eleven out of the 17 children still did not use self-referential pointing, suggesting that identification in autism is weak and may be reflected in social communicative deficits and cognitive inflexibility that is so pervasive in ASD.

Hobson and Hobson (2007) reviewed their hypothesis positing that an abnormality in *identification* is at the core of the development of autism. The authors paraphrased the definition of identification used by Laplanche and Pontalis (1973, cit. in Hobson & Hobson, 2007). The process was defined as relating to another's actions or attitudes from the other person's perspective *and* assimilating the other's orientations to the point where they become part of one's own psychological repertoire (Hobson & Hobson, 2007). According to this theory, when identification is the true motivation in imitating another, then the imitation attempt would transcend beyond mere copying of actions to include the style and the self-other orientation of another's actions. This is true *assimilation* of another's beliefs and this is an important distinction when understanding that identification cannot be reduced to perceptual skills (Meyer & Hobson, 2005).

2.2.3 Theory of Mind

The widely acknowledged difficulty in social communication and social interaction evidenced in individuals with autism has predominantly been addressed using the most prevalent cognitive theory of autism to date, the Theory of Mind hypothesis (Baron-Cohen, 1995; Baron-Cohen, Leslie, & Frith, 1995). Based on the concept of 'mentalising', this theory attempts to explain how humans can take another perspective and attribute mental states to those around them; and more importantly, why autistic individuals might not demonstrate this same ability. The inability to "automatically take into account the mental states of people, their desires and their beliefs" is a fundamental cognitive deficit in autism; resulting in the hallmark feature of the mindblindness hypothesis (Baron-Cohen, Leslie, & Frith, 1985; Frith, 2001, p. 970). The difficulty lies in forming mental representations, the inability to attribute mental states to others – being 'blind' to others' minds. After years of research using false-belief tasks originally designed by Wimmer and Perner (1983) to test first-order beliefs such as "I think he thinks", more complicated second-order and advanced tests were developed (see Rajendran & Mitchell, 2007 for review). Characterising the types of mentalising tasks that posed challenges to individuals with autism as well as identifying the specific level of breakdown in their performance, contributed to the development and the evolution of the theory. For example, not all individuals with autism fail first and second-order theory of mind tasks (Bowler, 1992 as cited in Rajendran & Mitchell, 2007) and these findings further informed the theory. Following new reports, the tests were adapted and refined, leading to further questions about the necessary skills and cognitive abilities necessary to pass these tasks. Why do some autistic individuals pass these tests and others fail? Is there a developmental trajectory or maybe theory of mind is not an 'all or nothing' response. To test theory-of-mind skills, children are presented with a story in which Sally (the girl on the left) has a basket, and the girl on the right named Ann, has a box. The story proceeds where Sally puts her marble in the basket and leaves the room. Whilst Sally is away, Ann takes the marble from the basket and puts it in the box. The false belief task begins when Sally returns to look for the marble and the examiner

asks the participant where Sally will look for the marble. See Fig. 2.2 for the storyline of the Sally-Anne false belief task.

Frith (2001) provided an alternative view arguing that all individuals are born with an innate ability to mentalise although, “a newborn child does not possess fully functioning mentalizing ability” (Frith, 2001, p.970). She suggested that skills such as joint attention and gaze shifting are *precursors* to the development of understanding the mental state of others (Charman et al., 1997; Frith, 2001) and that interaction with caregivers and the social environment sets the stage for learning about mental states of others. The theory of mind hypothesis does not explicitly account for the imitation deficits in autism. Nevertheless, according to the theoretical stance of Frith, the findings that typically developing children as young as 18 months, pass imitation tests designed to test the understanding of others’ goals and intentions would imply that mentalising precedes the development of imitation.

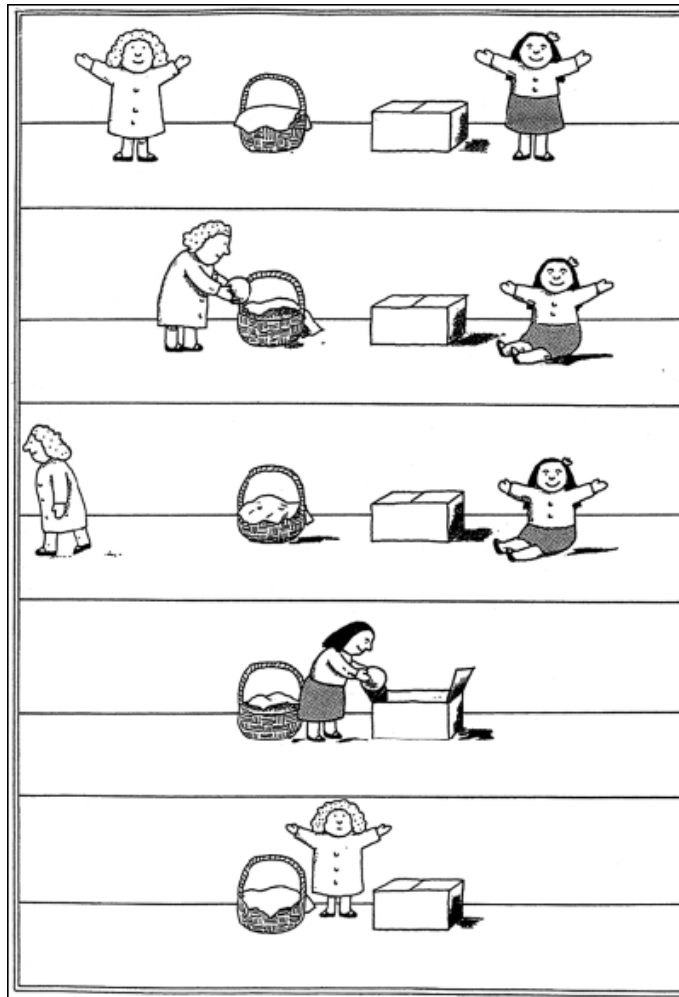


Figure 2.2. The Sally–Anne false-belief task. cit. in Frith, U. (2001). Mind blindness and the brain. *Neuron*, p. 971.

2.2.4 Self-Other Mapping Hypothesis

In 1991, Rogers and Pennington published a theoretically integrative approach to infantile autism founded on the developmental and biological accounts of Meltzoff (1988), Stern (1985, cit. in Rogers & Pennington, 1991), and others, taking into consideration the core deficits of imitation, affective sharing, and theory of mind in autism spectrum disorders. This hypothesis suggested that humans appear to be born with an innate system that is prewired to develop infant imitation, emotion sharing, and theory of mind. Through a complex hierarchical process of

development of self and other awareness, the infant grows to understand social knowledge. Rogers and Pennington suggested that this new theoretical approach should be described as ‘a cascade model’ because each core component has an effect on future developmental processes; a deficit in one area would thereby create a cascading effect of impairments in the development of core skills such as joint attention and symbolic play in autistic children. The authors stressed that although the hypothesis put forward by Baron-Cohen, Leslie, and Frith addressed the social deficits in autism, a new hypothesis that integrated the areas of core deficits in autism within a developmental model was essential. “The potential power of an early deficit in imitation to disrupt other early developing interpersonal processes” clearly placed imitation squarely in the center of this theoretical account (Rogers & Pennington, 1991, p.137).

Outlining the self-other mapping representational hypothesis, Rogers and colleagues suggested that individuals with autism have difficulty forming and coordinating representations; specifically, the representations that “extract patterns of similarity between the self and other” (Rogers & Pennington, 1991, p.151). Subsequently, a deficit in the ability to form these critical representations of self and other would be of importance to the future development of individuals with autism.

Not only was this influential hypothesis founded on a biologically based model, but it also included a biological extension and neuropsychological considerations (i.e., the brain-behavior link). A brain-behavioural link implicating the frontal lobe resulting in the disruption of imitation and the ability to develop the self-other awareness is central to the theory. Building on Meltzoff’s infant imitation studies (Meltzoff, 1988; Meltzoff & Moore, 1977) the authors suggested that infants are biologically ready for imitation when they are born and hypothesized that the prefrontal cortex was implicated in the self and other representational mapping process. Explaining that the prefrontal cortex appeared particularly well-suited for this task, the authors reviewed the neural connections potentially recruited in the mapping of these representations. The prefrontal cortex has connections to both the limbic system and the posterior cortex and some of them may not function normally

thereby altering the development of representations of self and other necessary for development of social interaction and affective sharing.

In imitation in autism, error patterns including errors of reversal (“recreating the hand view that they see instead of translating the perspective the other had seen”: Williams et al., 2001, p. 8), partial imitation (imitating only part of a gesture), and problems with mirror image (imitating the examiner as if looking in a mirror) have all been identified (Avikainen, Wohlschlager, & Hari, 2003; Ohta, 1987). Ohta (1987) was the first to describe partial imitations in autism and concluded that they indicated a disorder rather than a delay of gesture imitation. This error type was only observed in very young children in the comparison group but was a common error in the autistic group. Ohta (1987) suggested that the autistic children viewed the hands, face, and other body parts as separate entities and that they did not represent them as a whole body in their mental images. Therefore, this would be considered a disorder of mental body images or possibly even representations. Mirror image imitations were not counted as correct or incorrect in this study. Avikainen and colleagues (2003) published their findings of deficits in mirror image imitation in a group of high-functioning individuals with autism. Whilst the typically developing group demonstrated an advantage in the mirror condition, the individuals with autism showed more errors in hand choice and grip position in this condition, differing from the performance of the control group. Body part orientation errors in the imitation of meaningless gestures suggest that individuals with autism have difficulty “seeing others as a template of the self”. These findings suggest that this difficulty may be, in part, due to problems in determining the relations of body parts to each other (cf. Goldenberg & Hermsdorfer, 2002).

2.2.5 Mirror Neuron Theory

The self-other mapping hypothesis put forward by Rogers & Pennington (1991), implicated a brain-behavioral link contributing to the deficits of imitation in autism; however, it was the discovery of mirror neurons (di Pelligrino, Fadiga,

Fogassi, Gallese, & Rizzolatti, 1992; Rizzolatti, Fadiga, Fogassi, & Gallese, 1996) that sparked a resurgence of research in the field of imitation.

The mirror neuron hypothesis extended the self-other mapping theory arguing that the dysfunctional development of the mirror system in individuals with ASD was the underlying neurophysiological mechanism responsible for the noted deficits in self-other mapping as well as the social cognitive deficits so prevalent across the autism spectrum (Williams et al., 2001). This influential hypothesis has provided a possible neurobiological explanation for the reported imitation deficits and the pervasive social impairments observed in individuals with autism.

In the ventral premotor region in monkeys, neurons have been observed that fire *both* during observation and during execution of actions and have been termed ‘mirror neurons’ (Fadiga, Fogassi, Gallese, & Rizzolatti, 2000). Evidence for a mirror system in humans (similar to F5 in monkeys) has also been reported in various types of neuroimaging studies. Results from transcranial magnetic stimulation (TMS) studies demonstrated an increase in motor activity in corresponding areas during the participants' perception of others performing activities (Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995). This finding of neurons firing during observation and action supported theoretical constructs of coupling between the action and perception systems (Rogers & Williams, 2006). The discovery and study of mirror neurons has furthered the research in the field of imitation leading researchers to suggest that a common coding exists between ‘self and other’ as a shared representational network (Meltzoff & Decety, 2003).

The suggestion that the reported types of imitation deficits documented in the autism literature offered clues to the underlying dysfunction of a neurobiological construct has been put forth by Williams and colleagues (2001). These observations in the imitation performance in individuals with autism included worse performance in meaningless gesture imitation over meaningful gesture imitation, improved imitation of actions with objects, production of reversal errors (Williams et al., 2001), and difficulty performing unconventional actions with objects. Taken

together, the authors suggested that a mirror neuron deficit may be impeding the development of a fundamental ability in mapping the actions of others accurately in order to achieve the production of an imitative match of the actions of others to the actions of oneself (Williams et al., 2001).

Although the imitative deficits observed in autism have been suggested to be related to a dysfunctional mirror neuron system, the relationship between a deficit in 'common coding' and selective deficits of imitation performance in autism is not yet well understood. Some researchers have suggested that mirror neurons may be implicated more in one imitation type than another; for example, in the direct route of meaningless gesture imitation over meaningful actions (Rumiati et al., 2005). Others have challenged this account by showing that individuals with autism perform certain imitation tasks without difficulty suggesting that a dysfunctional mirror system alone is not at the core of the imitation deficit (Hamilton, Brindley, & Frith, 2007; Leighton, Bird, Charman, & Heyes, 2008). Hamilton et al. (2007) argued that the mirror neuron system is believed to support not only action, but action understanding; therefore, following this theory, tasks tapping into the recognition of gestures should also be impaired. They tested 22 children with ASD and 30 typically developing children and found that the ASD group did not demonstrate impairment in gesture recognition and even outperformed the control group on this task. Designing tasks specifically implicating brain areas included in the mirror neuron system, the authors tested three action tasks: Goal-directed imitation (i.e., covering objects with right or left hand), mirror imitation, and grasp planning. Results revealed that the ASD group did not demonstrate any impairments in the skills that were included to test the mirror neuron theory (i.e., mirror imitation). Similar results of gesture recognition abilities in autism have also been reported by other autism researchers (Smith & Bryson, 1998; Smith & Bryson, 2007) although the materials and stimuli differed across studies. For example, Smith & Bryson (2007) produced a pantomime (e.g., gestures that demonstrate object use) intransitive gesture (e.g., social gestures, such as "waving") and asked the participants to verbalise the gesture. Other options were provided if the participant did not produce a verbal response.

Hamilton et al. (2007) asked the participants to match a picture of a hand posture to a cartoon drawing of an action with hands missing. As an example of the stimuli used in this task, a picture of a woman ironing was presented as well as 3 picture choices and the participant was required to identify the correct hand posture. Terminology for gesture recognition, gesture reception, and comprehension tasks has been used differently by different researchers and in some studies, gesture recognition was part of the gesture memory task (Rogers et al., 1996). Another error type considered indicative of mirror neuron dysfunction in ASD is that of a reversal in hand position. Reversal errors, as discussed in the self-other mapping theory, are also of interest in autism and have been reported in a variety of studies with implications to self and other representations (Ohta, 1987; Smith & Bryson, 1998)

Interestingly, one argument against a mirror neuron account of autism reported findings that individuals with high-functioning autism performed equally as poorly on tasks of imitation as they did on non-imitative tasks including verbal and geometric tests (Leighton et al., 2008). However, others may argue that an impaired mirror system would not only affect goal directed imitation but would also have an impact on mother-infant social communication and interaction thereby having a profound impact on the development of speech and language (Hobson, 2002; Rogers & Pennington, 1991). The role that the mirror neuron system is thought to play in the development of language and imitation is complex and it has been suggested that “perception, imitation, and spontaneous production of language are superimposed on a broadly distributed set of neural systems” (Bates & Dick, 2002, p. 6) and that “division of language in the brain does not appear to break down neatly into language versus non-language” (Bates & Dick, p. 12). Smith and Bryson (2007) interpreted these conflicting results in tasks predicting mirror neuron dysfunction as evidence used to rule out a simple representational deficit in autism. The authors stressed the importance of further study into the praxis processing in individuals with autism.

2.2.6 Theory of Executive Dysfunction

An executive dysfunction explanatory theory of autism is often referred to as an ‘umbrella term’ that encompasses cognitive functions that are considered to be core deficits in the triad of symptoms of individuals with autism spectrum disorder (Griffith, Pennington, Wehner, & Rogers, 1999; Hill, 2004; Rajendran & Mitchell, 2007). Abilities including planning, mental flexibility, working memory, attention, inhibition, and generativity have all been considered under the umbrella of executive functions (EF: Griffith et al., 1999; Rajendran & Mitchell, 2007; Stuss & Knight, 2002 cit. in Hill & Bird, 2006). Due to the somewhat ‘vague’ definition of executive functioning (Hill & Frith, 2006), interpretation of the performance of executive functions tasks in autism is not always straightforward. A host of ‘classic tests’ of executive functions have been used over the years including tower tasks, The Trail Making Test, Wisconsin Card Sort, the Stroop test, and measures of verbal fluency (Hill, 2004; Rajendran & Mitchell, 2007); however, these tests may not be sensitive to developmental executive dysfunction in the same way as they are for patients with acquired executive dysfunction (Hill & Frith, 2006). It is not only important to administer a range of developmentally appropriate tasks but also to integrate tests of executive functioning within the targeted context when assessing the association of EF to other autism deficits.

The role that executive functioning plays in imitation and the association between tasks of executive function and notable impairments of imitation in autism, whilst not completely understood, are of importance in furthering our understanding of the nature of behaviours associated with the triad of impairments in ASD. Systematic reviews of the evidence of executive dysfunction and its impact on imitation performance in autism have yielded inconsistent evidence and/or partial support. The role of attention, working memory, mental flexibility, set shifting, and inhibition have all been investigated in a variety of imitation tasks in ASD (Smith & Bryson, 2007; Rogers, Stackhouse, Hepburn, & Wehner, 2003; Vivanti, Nadig, Ozonoff, & Rogers, 2008).

Visual attention is an important area of investigation in imitation and an area of interest under the umbrella of executive dysfunction. The impact of multiple shifts of visual attention often required to complete the gestural testing battery has led some researchers to investigate the effect of these attentional shifts on imitation performance (Vivanti et al., 2008). For example, the participant may be required to look at a model's face, body, and the elicited action throughout the task, thereby shifting gaze multiple times (Rogers & Williams, 2006). Although difficulties in attentional flexibility have been reported (Ozonoff, Strayer, McMahon, & Filloux, 1994), the relationship between visual attention and imitation in autism and the use of eyetracking studies and gaze monitoring in imitation is in its infancy. One of the first published findings of an eyegaze experiment measured visual attention patterns in 18 high-functioning individuals with autism as well as 13 typically developing children (Vivanti et al., 2008). The groups did not differ in age, IQ, language level, or gender ratio.

The imitation battery they administered included meaningful actions with objects (e.g., striking a xylophone) and meaningless gestures (e.g., bending the arm at the elbow) and the experimental stimuli included 12 video clips showing the same actor performing different actions. As the participants watched the screen, his or her eye movements were recorded and the imitation productions were also coded resulting in a total score. Results indicated that the ASD group was less accurate than the TD group in imitating both meaningful actions with objects and meaningless gestures; however, their productions were better in imitation of meaningful actions with objects. Importantly, motor abilities did not contribute to their performance. Visual attention results revealed that both groups looked more to the action region while observing meaningful actions than when they observed meaningless gestures, and both groups looked more to the face region whilst imitating meaningless gestures. Although the same pattern was observed, the ASD group spent half as much time looking at the face region as the TD group. Although reliable differences in visual attention between the groups were identified, especially during meaningless gestures, the authors stated 'unequivocally' that individuals with autism do not have imitation difficulties

because they pay less attention to the action region. Results could not be explained by other executive dysfunction abilities such as disengaging from a stimulus or shifting attention. The authors suggested that these findings of action understanding processing in autism appear to be inefficient for the completion of the task.

Mixed findings have been reported in tests of working memory in individuals with autism. Recently, results of working memory studies in autism reported that in a group of adolescents with AS, no working memory deficits were revealed; however, deficits were identified in tasks measuring verbal short-term memory (Alloway, Rajendran, & Archibald (in press). In imitation studies in ASD, working memory and its relationship to imitation performance has also been evaluated, although the methodology has varied across studies (Bennetto, 1999 cit. in Vivanti et al., 2008; Rogers et al., 1996; Smith & Bryson, 1998). Working memory is important to evaluate because it may act as a workspace allowing activated semantic and procedural information to be manipulated whilst new programmes are executed (Bartolo, Cubelli, Della Sala, & Drei, 2003).

In other imitation and autism studies, Rogers et al. (1996) did not find a relationship between tests of visual recognition memory and pantomime imitation in the individuals with high-functioning autism. The memory task used was a matching task, testing recognition, in which the participant was instructed to indicate which picture matched the gesture performed by the examiner. Smith & Bryson (1998) also tested working memory using a matching task. The participants were asked to point to the target gesture after viewing manual and bimanual postures. It appears that when working memory was tested in the context of gesture recognition, group differences were not identified, but in other autism studies, working memory deficits have been reported. In two neuropsychological tasks, a working memory task measuring delayed response was correlated with immediate imitation performance in individuals with autism (Dawson, Meltzoff, Osterling, & Rinaldi, 1998).

2.3 A NEUROPSYCHOLOGICAL THEORETICAL ACCOUNT: DYSPRAXIA IN ASD

2.3.1 Challenges in Interpreting Imitation Research in ASD

Comparing studies of imitation in autism poses many challenges secondary to terminology inconsistencies, procedural differences, and the range of imitation types under study. Imitation studies in autism includes research in *emulation* or ‘goal imitation’, defined as imitating one’s goal rather than the specific steps that requires the participant to be aware of another’s intention (Carpenter, Pennington, & Rogers, 2001); *mimicry*, the study of automatic contagion or automatic matching of others’ behaviours considered to be an automatic response (Moody & McIntosh, 2006); *elicited imitation* referred to as the ‘do as I do’ procedure and defined as assessing “the ability of the participant to respond on demand to an unfamiliar experimenter usually in a laboratory setting” (Smith, Lowe-Pearce, & Nichols, 2006, p. 383); and *spontaneous imitation in natural settings* defined as “selective production of spontaneous imitations” in which a child makes a choice in the types of actions to be imitated (Nadel, 2006, p. 119). Mimicry, or ‘automatic contagion’, for example, may require different underlying systems for processing than imitating a skilled motor action on command (Moody & McIntosh, 2006).

Even within the category of elicited imitation, the classification of terms is complex and gestures have been defined in separate studies as ‘actions on objects’ (Rogers et al., 2003 p. 769) ‘facial-oral gestures’ (Loveland, et al., 1994, p. 434); ‘body movements’ (Stone et al., 1997, p. 479); ‘body imitation’ (DeMyer et al., 1972 p. 264); ‘pantomimes’ (Rogers et al., 1996, p. 2065); ‘symbolic gestures’ (Smith & Bryson, 2007 p. 1); ‘non-symbolic postures’ (Smith & Bryson, 1998 p. 747); ‘skilled motor gestures’ (Mostofsky et al., 2006 p. 314) ‘motor imitation’ (Jones & Pryor, 1985 p. 37) and ‘intransitive gestures’ (Mostofsky et al., 2006 p. 317)

In addition to terminology challenges, procedural variations also exist from one study to another. Hobson and Lee (1999) reported findings of imitation impairments of meaningless actions towards objects (e.g., strumming a pipe rack with a stick and wiping one's brow with a toy frog) after a ten minute delay whilst other studies reported results of immediate imitation.

Another problem is that different types of gestures are often mixed together in one list (non-symbolic, orofacial, meaningful, pantomimes: Beadle-Brown and Whiten, 2004). Although the nine categories of elicited imitation Beadle-Brown and Whiten (2004) tested were comprehensive, they included imitative actions across categories such as 'vocal', 'facial', 'body related-invisible and invisible', 'one and two hand', and 'whole body' and tested meaningful and meaningless gestures in a mixed list of 16 gestures to administer on two separate sessions. In other recent studies gesture types have been combined. Transitive gestures (meaningful object use, e.g. use of a pen) and 'meaningless actions with objects' (e.g. walk hairbrush across table) were combined to achieve one 'elicited imitation' score (McDuffie et al., 2007). In other studies, intransitive gestures (communicative gestures, e.g. waving goodbye) were evaluated together with meaningless gestures under the label, 'body movements' (Stone et al., 1997). All of these results are difficult to interpret since the order of administration and the content of lists (meaningful or meaningless gestures) elicits 'list effects' and can affect imitation performance when both types of gestures (meaningful and meaningless) are combined together (Cubelli, Bartolo, Nichelli, & Della Sala, 2006; Tessari, Canessa, Ukmar, & Rumiati, 2007). Therefore, it is not only important to consider the types of gestures tested but also to be aware of the terminology inconsistencies and the procedural variations in the study when comparing results.

Deficits have been reported in imitating meaningless actions (DeMyer et al., 1972; Ohta, 1987; Rogers et al., 1996; Smith & Bryson, 1998) but meaningful gesture findings have been published with mixed results. Rogers et al. (1996) reported that meaning appeared to improve gesture performance for single sequences

whilst others have reported deficits in the imitation of both meaningful and meaningless gestures (Smith & Bryson, 1998; Smith & Bryson, 2007; Mostofsky, 2006).

2.3.2 Implications for Imitation and Dyspraxia Research in ASD

These reported conflicting findings have led researchers to suggest that the imitative system is not unitary and different underlying cognitive representations appear to be important for accurate performance of imitation tasks (Hamilton, Brindley & Frith, 2007; Hamilton (2008); Mostofsky et al., 2006; Rogers et al., 1996; Smith & Bryson, 1994). Indeed, individuals with autism do not perform all imitative tasks equally and performance appears to be task dependent. (Mostofsky et al., 2006; Hamilton et al., 2007). Theoretical explanations are needed that account for these findings, taking into consideration the fractionation of the gestural system in ASD. The following chapter presents a theoretical argument addressing the fractionation of performance of gestural processing in ASD.

CHAPTER 3

A NEUROPSYCHOLOGICAL APPROACH TO LIMB APRAXIA

3.1 A DYSPRAXIC ACCOUNT OF GESTURAL PROCESSING DEFICITS IN AUTISM

3.1.1 Definition of Apraxia

Apraxia is a term that is often misunderstood and one that has been used to describe a wide range of neurobehavioural and movement disorders since the beginning of the 20th century. Identified disturbances have included gait apraxia, dressing apraxia, construction apraxia, swallowing apraxia, gaze apraxia, truncal apraxia, limb apraxia, and speech apraxia to name a few (De Ajuriaguerra & Tissot, 1969; Rothi & Heilman, 1997). The underlying etiologies of these disorders often vary significantly and not all involve deficits in skilled movement (Hacean & Rondot, 1985). Therefore, De Ajuriaguerra and Tissot (1969) proposed that the umbrella term of apraxia be abandoned and they called for descriptions of distinctly different varieties of apraxias. Apraxia, taken from the Greek "a" = without and "praxis" = actions, is an impairment in gesture performance defined as a deficit of purposeful movements which cannot be explained by elementary motor or sensory defect, task incomprehension problems, or inattention to command (De Renzi & Faglioni, 1999).

Deficits in praxis processing have been reported in both adult and paediatric patient populations and may present itself as a result of an acquired neurological insult (Liepmann, 1905 cit. in Goldenberg, 2003; De Renzi & Luchelli, 1968; Cubelli, Marchetti, Boscolo, & Della Sala, 2000; Rothi, Ochipa, & Heilman, 1991) or may take the form of developmental dyspraxia; one resulting without any observable brain lesions (Cermak, 1985; Gubbay, 1975; Sanger et al., 2006). The major differentiation between the two is the time of onset; in an acquired disorder

skilled movements were present and were subsequently lost after a neurological event and in developmental dyspraxia, the skills were not acquired from birth. Although individuals with developmental dyspraxia often present with coordination difficulties, the important key feature is that in both apraxia and developmental dyspraxia, the disorder of skilled movement cannot be attributed to motor deficits alone (Mostofsky et al., 2006; Sanger et al., 2006). The history of acquired apraxia will now be outlined.

3.1.2 Introduction to Dyspraxia

Although imitation has been studied extensively over the years, to date, a single hypothesis has not been supported that fully accounts for the imitative deficits observed in ASD (Smith & Bryson, 2007). Smith and Bryson (2007) state that unlike other theoretical explanations of imitation deficits in autism, their position does not suggest that the core deficit underlying problems with imitation in autism is the inability to understanding others' psychological states, but rather is grounded in the notion of a deficit of motor movement representations. Further, their approach "stems from a different tradition, focusing instead on the component skills that contribute to various aspects of praxis, situating imitation within that context" (Smith & Bryson, 2007, p. 2). Apraxia is a deficit in gesture processing that affects not only imitation but also recognition and comprehension of gestures as well as gesture production. Limb apraxia has been described as "a cognitive-motor disorder that is especially intriguing because the symptoms underscore the intimate and complex functional connections among internal cognitive operations and the physical motor event" (Harrington & Haaland, 1997, p. 112). However, before the "nature and integrity" of these movement representations and execution systems (Smith & Bryson, 2007, p. 2) can be fully understood, it is imperative that the praxis models used to interpret gesture performance are thoroughly investigated.

Differing from previous imitation theories, the following theoretical approach

stems from a neuropsychological perspective focusing on the underlying cognitive mechanisms and core skills that contribute to praxis (gestural) processing in autism (Mostofsky et al., 2006; Smith & Bryson, 2007; Vanvuchulen, Roeyers, & DeWeerd, 2007). Therefore, in an effort to gain a more thorough understanding of the challenges of studying developmental dyspraxia in autism, a review of the history of apraxia in neuropsychological studies of adults will be presented followed by an overview of the development of cognitive models of praxis processing. Next, an outline of the history of developmental dyspraxia will be reviewed and the studies of dyspraxia in autism will be discussed. Finally, the usefulness of applying adult models to paediatric populations will be addressed.

3.2 HISTORY OF APRAXIA

3.2.1 “Grandfather of Apraxia”

Over 100 years ago, in 1900, Hugo Liepmann published a detailed case study of a patient, diagnosed with syphilis, that he described as the “Regierungsrat” translated as senior civil servant, M.T. (Faglioni & Basso, 1985). This patient was observed to fail at almost everything that he was asked to do with his right hand, including pointing to and using objects, but he did not demonstrate the same impairments when using the left hand. Furthermore, the patient understood the instructions and understood what was expected of him but was unable to perform the actions using the right hand (Liepmann, 1905 cit. in Goldenberg, 2003).

According to Liepmann, the deficit could not be attributed to lack of comprehension, asymbolia, general intellectual impairment or visual disturbances and this finding was the beginning of the identification of apraxic syndromes described by Hugo Liepmann. The impact that his research had in the field of neuropsychology cannot be underestimated; the syndromes that he identified in the early 1900’s have become so iconic that the same descriptions and definitions

of apraxia are often reported today.

Liepmann was a student of Karl Wernicke. Wernicke is perhaps best known for his description and analysis of aphasic syndromes, specifically the identification of Wernicke's aphasia, a disorder in the comprehension of spoken language. Most notably, Wernicke explained aphasia in terms of information-processing modules and defined the 'representations' as information contained in each specific module (Rothi & Heilman, 1997: See Fig. 3.1.)

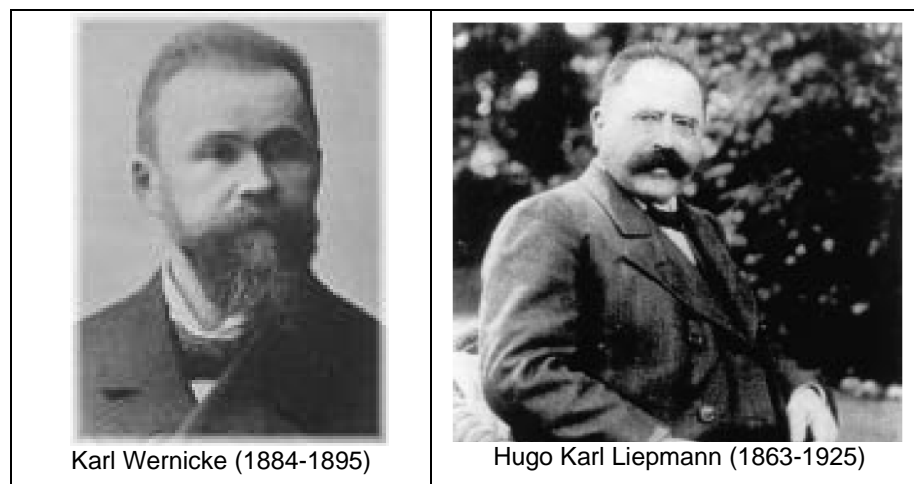


Figure 3.1. Founding fathers of aphasia and limb apraxia.

Using the same analytical and descriptive approach as Wernicke used for aphasia, Liepmann set out to describe and analyse apraxic syndromes. Although Liepmann was not the first to use the term 'apraxia', he was the first to suggest that apraxia was not attributable to 'asymbolia' and was not merely the result or an extension of aphasia as previously described by Finkenburg (1870, cit. in Goldenberg, 2003) or a disorder of the relationship between the movements and the objects as suggested by Steinthal (1871, cit. in Rothi & Heilman, 1996).

It is true, aphasia and apraxia may occur together, but one does not influence the other in terms of severity and they also may occur independently of each other,

thereby providing evidence against asymbolia as a necessary precursor to apraxia (Goodglass & Kaplan, 1963). Liepmann outlined three types of apraxia: Ideational apraxia; motor apraxia or ‘ideo-kinetic apraxia; and limb-kinetic apraxia (see Goldenberg 2003 for a review). Ideational apraxia was defined as the inadequate formulation of the motor programme (i.e., not knowing what to do) and ideo-kinetic apraxia was described as the disruption of the transmission of the motor programmes (i.e., knowing what to do but not being able to do it). Lastly, limb-kinetic apraxia as an “extended concept of apraxia” and referred to deficits in “memories of an extremity” (Liepmann, 1908a, cit. in Goldenberg, 2003 p. 519).

From the beginning, the definition of ideational and ideomotor apraxia has been used differently by various researchers and there has not been a universal consensus on the terms, although many still cite Liepmann’s original dichotomy. Pick (1905) used the term ideomotor apraxia to characterize errors that were a result of the inability to access the appropriate idea of the movement. He hyphenated ideo-motor to make a clear distinction that there appeared to be a separation between the idea and the motor implementation of the idea. Liepmann designated Pick’s version of apraxia, *ideational* apraxia and not ideo-motor apraxia (Goldenberg, 2003) and contrasted these to ideo-kinetic apraxia. Morlaas (1928 cit. in Goldenberg, 2003) referred to motor apraxia as ideo-motor apraxia and ideo-motor apraxia as ideational apraxia and these are classifications that are still used today.

3.2.2 Ideational Apraxia

One of the first original reports of an ideational apraxia was published by Pick (1905) of a patient who used a razor as a comb and a scissors as a pen (Pick, 1905 cit. in De Renzi, 1985). Not only was the patient unable to correctly use tools and objects, but he experienced difficulty with sequencing tasks. Pick did not believe that the patient’s errors were related to agnosia because he could perform tasks of object naming (Heilman & Rothi, 1997).

Many researchers consider ideational apraxia (IA) to be a disorder of sequencing whereby patients show impairments when performing complex actions requiring multiple objects used in the correct fashion and correct order (Pick, 1905 cit. in De Renzi, 1985; Poeck, 1985). Therefore, tasks combining multiple single actions into a sequence would theoretically bring out IA (e.g., preparing a cup of coffee: Poeck, 1985). Liepmann highlighted the effect of complexity as he described the simplest test for ideational apraxia being the task of lighting a candle or using it to seal (1920, cit. in Heilman & Rothi, 1997).

Although ideational apraxia does tend to manifest in sequencing tasks, others have suggested that ideational apraxia is also observed in the performance of single actions but may merely be easier to detect in complex tasks (De Renzi, 1985; De Renzi & Faglioni, 1999; Morlaas, 1928 cit. in De Renzi, 1985). In another view, Morlaas (1928) suggested that the main disturbance in patients with IA was the inability to evoke the correct gesture necessary for the appropriate use of the object and used the term “agnosie d’utilization” (“agnosia of utilization”). Heilman (1973) suggested that IA is a deficit of execution of gestures to verbal command but not to imitation.

De Renzi (1985) outlined various methods of examining gestures and discussed their bearing on the interpretation of apraxia. He suggested that pantomimes (the mime of object use) are the most useful tests to bring out ideational apraxia because the patient is required to retrieve the memory of a gesture and this is an ability that precedes the implementation of the motor plan. He reported findings of a study comparing 150 left brain damaged (LBD) patients on two tasks; one for imitation and the other for pantomime of object use in the visual modality and a subgroup of patients demonstrated a selective impairment in pantomimes (De Renzi, Faglioni & Sargato, 1982, cit. in Heilman & Rothi, 1997). Therefore, he recommended in clinical practice that the ‘sounder basis’ for the diagnosis would be a task in which the patient would be required to evoke the gesture rather than be required to imitate. See Fig. 3.2 as an example of a patient presenting with

ideational apraxia.



Figure 3.2. Example of ideational apraxia. Cubelli, R., Marchetti, C., Boscolo, G. & Della Sala, S. (2000). *Cognition in Action, Brain and Cognition*.

Ochipa, Rothi, and Heilman (1989) put forth another classification system to distinguish sequencing from conceptual error patterns: Ideational and conceptual apraxia respectively. They described patients demonstrating errors of ‘content’ in their gesture production while being skilful in the acts that they produce (Rothi, Ochipa & Heilman, 1991). Ochipa, Rothi, and Heilman (1989) reported findings of a patient who named objects correctly but used the same objects inappropriately (e.g., using a tube of toothpaste instead of a toothbrush to brush his teeth). Moreover, IA patients may show difficulty performing tasks eliciting non-production errors including gesture matching and recognition (Bartolo, Cubelli, & Della Sala, 2008; Cubelli et al., 2000). In clinical practice, patients with ideational apraxia may be misdiagnosed as experiencing mental confusion therefore; patients need to be carefully assessed in these situations because ideational apraxia often co-occurs with Alzheimer’s disease (Herbert & Roy, 2002).

3.2.3 Ideomotor Apraxia

Ideomotor apraxia has been defined as “a disorder that occurs when patients fail to implement the mental representation of a gesture in a motor programme that specifies the correct innervation of the involved muscles” (De Renzi & Faglioni, 1999, p. 421). The conceptual component of the gestural system is preserved; therefore patients would perform classification tasks and retrieve gestural representations without difficulty (Bartolo et al., 2008; Cubelli et al., 2000). Observable error patterns of shape, order, and spatial temporal features would be evident during gesture production (De Renzi & Faglioni, 1999; Heilman & Rothi, 1997).

In testing IMA, intransitive gestures were traditionally considered an effective measure of bringing out IMA because the motor acts were considered well-practiced and contained a definite conformation making it easy to compare them to a standard production (De Renzi, 1985). However, De Renzi (1985) raised the pertinent question as to whether an ideational component may be involved in the production of a symbolic gesture when retrieving the gestural representation, and he suggested that there is no reason to restrict tests of IA to object use only positing that IA can extend to any movement pattern that has previously been learned.

Subsequently, De Renzi & Faglioni (1999) suggested that imitation is the most expeditious way to test IMA because imitation bypasses the ideational stage and also eliminates the demands of verbal comprehension. More specifically, meaningless gestures were suggested as being a more effective measure of IMA than the imitation of meaningful gestures but this study of meaningless movements was published in an Italian journal and its contribution to apraxia research was overlooked for many years (Pieczuro & Vignolo, 1967 cit. in De Renzi, 1985). The authors reported their findings that patients with LBD found imitation of meaningless movements more difficult than meaningful movements and that RBD patients performed imitation of meaningless gestures similar to

normal controls. They posited that meaningless movements are not rehearsed and require a higher degree of motor control than symbolic, overlearned gestures and are more easily disrupted suggesting that they are better determiners of ideomotor apraxia.

In ideomotor apraxia, the conceptual component of the gesture is intact, therefore, patients should be able to use tools and objects appropriately (De Renzi & Faglioni, 1999). Conversely, Heilman & Rothi (1993) and Buxbaum and colleagues (2005) suggest that ideomotor apraxia patients demonstrate the greatest difficulty in tasks of make believe transitive gestures (e.g., pantomimes). Patients make errors of perseveration, sequencing, orientation, and spatial movement. However, Heilman & Rothi (1993) suggest that spatial errors are the most characteristic errors evident in ideomotor apraxia.

3.2.4 Gesture Types

In limb apraxia, two main gesture categories have traditionally been evaluated: Meaningful and meaningless gestures. Meaningless gestures are gestures or actions that do not contain a semantic component and are usually elicited in imitation modality. Meaningful gestures are further classified depending on the aim of the action; for example, to manipulate an object (transitive) or mime object use (pantomimes), or to communicate ideas or feelings (intransitive) and they may be symbolic or expressive (De Renzi, 1985).

Meaningful Gestures

Three different types of meaningful gestures are traditionally tested in apraxia – transitive gestures, intransitive gestures, and pantomimes.

Transitive gestures

The definition of transitive gestures has often been used differently across apraxia studies, referring to the spontaneous use of objects (Bartolo et al., 2003; Cubelli et al., 2000) and/or as the mime of object use (Buxbaum, 2005). Transitive gestures involving tool use were thought to be the best way to bring out ideational apraxia (Morlaas, 1928, cit. in Heilman & Rothi, 1997). Patients were described using a razor as a comb and a pair of scissors as a pen (Pick, 1905, cit. in Heilman & Rothi, 1997), and this was considered as evidence that IA can exist in the use of single objects. Others have suggested that the use of familiar objects is a straightforward task and the tactile feedback provided by the object itself assists in the appropriate use of the tested object (De Renzi, 1985). Nevertheless, the inclusion of spontaneous use of objects remains an integral component of apraxia evaluation in clinical settings.

Intransitive Gestures

Intransitive gestures are often referred to as communicative or social gestures because they convey feelings and are used to express ideas without relying on object reference (Bartolo et al., 2008; Cubelli et al., 2000). Intransitive gestures are socially complex and bound to environmental and cultural contexts. For example, the meaning of a symbolic intransitive gesture in one country may be considered offensive in other countries and cultures. The well-known faux pas of Vice President Nixon making the 'ok' sign in Brazil during the 1950s is just one example of an intransitive gesture lost in translation. To Americans in the US, this gesture means that everything is A-ok or 'just fine' but it holds quite a different meaning in cultures such as Brazil where it is considered vulgar and degrading. From that point forward, Nixon used the victory sign throughout his presidency (see Fig. 3.3).



Figure 3.3. Richard M. Nixon making 'victory' gesture (AP Photo).

Hacaen & Rondot (1985) considered symbolic and expressive intransitive gestures as two different gesture categories because of the differences in the psychological state of the producer when making the gestures as well as in the differences in the underlying cognitive mechanisms recruited during production. Differing from the motor programs necessary for transitive gesture production, the task constraints for intransitive gestures rely upon an arbitrary link between the gesture and its meaning (Bartolo et al., 2008; Cubelli et al., 2000). Traditionally, researchers suggested that intransitive gestures were the best way to bring out ideomotor apraxia because these gestures were well-practiced and held a definite configuration.

Not only are intransitive gestures culturally bound by countries, but they can also vary depending on the geographical regions within the same country (see Fig. 3.4).



Figure 3.4. Examples of common gestures used in Nigeria, West Africa taken by Heidi Ham with permission to include in this thesis.

Pantomimes

In limb apraxia, the term transitive gesture has referred to both the use of objects and pantomimes (i.e., the mime of tool use). The inclusion of pantomime performance in apraxia batteries poses special challenges because pantomimes involve object use and could be considered as a transitive gesture, but at the same time they do not include the object during the mime and therefore could also be categorised as an intransitive gesture (Bartolo et al., 2003).

Bartolo et al. (2003) found that pantomimes appear to be a unique category of gesture requiring working memory to accurately perform, and therefore, the authors differentiated between transitive gestures and pantomimes. They defined transitive gestures as actual tool use and pantomimes as the mime of the tool use.

Moreover, the manner in which the pantomime is elicited also has an effect on production performance and instructions have varied across studies. Different instructions may predispose the participant to make specific error types. One type of error is defined as a body-part-as-object error (BPO) and occurs when the participant uses a body part as the tool in the actual gesture production (e.g., the patient uses their index finger to brush their teeth). Dumont, Ska, and Schiavetto (1999) instructed their patients to “Show me how you would brush your teeth” (p.

450) but this instruction does not provide specific information to the patient explaining that the mime of the use of the object is required. This specific instruction has been reported to result in the production of body-part-as-object errors (Bartolo et al., 2003). In contrast, Raymer and colleagues (1996) found that it was helpful to have the patient practise pantomiming before the session whilst instructing the participants to “actually imagine the object you are acting upon” (Raymer, Maher, Foundas, Heilman, & Rothi, 1996, cit. in Raymer & Ochipa, 1997, p. 62). Differing from the previous method, only the apraxic patients were found to produce body-part-as-object errors. Body-part-as-object errors may be a compensatory strategy in pantomime production (Heilman & Rothi, 1985). Contemporary apraxia batteries include both pantomimes and transitive gestures (e.g., Bartolo et al., 2008).

Meaningless Gestures

Meaningless gestures are novel gestures that do not carry any meaning (Bartolo et al., 2008). Meaningless gestures are of special interest to neuropsychological and developmental research secondary to the matching process required for their production as well as the lack of semantic content of the gesture itself (Goldenberg & Strauss, 2002). In 1967, Pieczuro and Vignolo, were the first to publish convincing findings when testing patients with left brain-damage, that meaningless gestures were actually better at revealing limb apraxia than were tasks of meaningful gestures (cit. in De Renzi, 1985).

3.3 HISTORY OF APRAXIA THEORIES

3.3.1 Liepmann’s Movement Formulas

Liepmann set forth the idea that the left hemisphere specialised in skilled movement for both the right and left sides and that the movements were generated by “movement formulas” or “innervatory patterns” for production of these skilled

actions (Kimura, 1980 cit. in Rothi & Heilman, 1985). He proposed that the movement formula communicated information about the gestures to the primary motor area and that “these movement formulas contained the time-space-form picture of the movement and assisted in adapting these memories to environmental conditions” (Rothi & Heilman, 1985 p. 65).

Liepmann (1905) described the apraxic syndromes (cit. in De Renzi & Faglioni, 1999; Rothi & Heilman, 1985) outlining the neuroanatomical correlates of the observable patterns of gesture production in brain damaged patients. De Renzi and Faglioni (1999) outlined the ‘essence’ of Liepmann’s interpretations and they are summarised below:

The stimuli coming from sensory areas on either the right or the left side of the brain merge in the sensory and motor area of the left hemisphere that Liepmann referred to as the *sensomotorium*. These ‘kinesthetic-innervatory engrams’ (memory for the innervations) are stored in this area and elicit the gestures. Therefore, a disruption of ideational or ideomotor apraxia could result depending on the type of error pattern observed. A deficit in creating a movement formula would result in an ideational apraxia. According to Liepmann, errors consistent with ideational apraxia would include conceptual and/or sequencing errors.
(De Renzi & Faglioni, 1999, p. 425)

The left figure appeared in his 1908 paper and the right one was published in 1925 (as cit. in Goldenberg 2003). Both figures describe the “translation from movement formula to motor execution” (Goldenberg, 2003, p. 520: See Fig. 3.5).

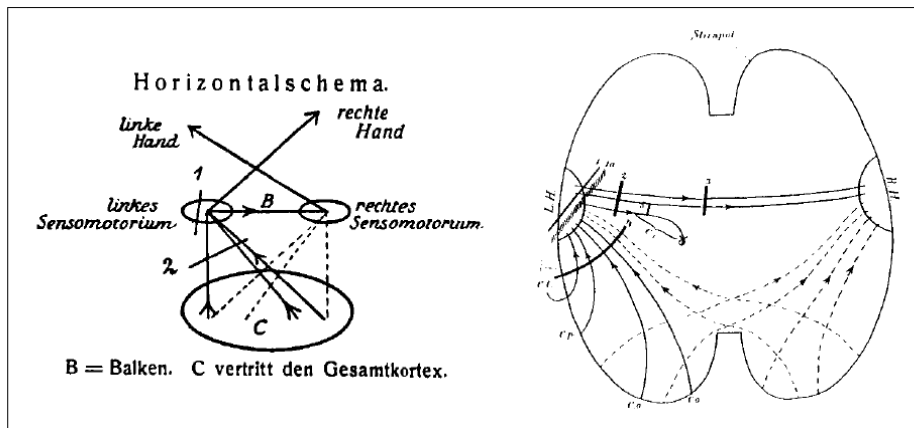


Figure 3.5. Liepmann's movement formulae.

3.3.2 Hemisphere Dominance

Since the time of Liepmann, a left hemisphere dominance for praxis has been reported. The onset of *left limb apraxia* following a colossal lesion, was one example confirming the importance of the left hemisphere according to Liepmann and Maas (1907) because the right motor area could not control gesture execution if it could not recruit the assistance of the left hemisphere (cit. in De Renzi & Faglioni, 1999). Liepmann and Maas (1907) suggested that the left hemisphere was instrumental in language and movement formulas that store important knowledge of movement of purposeful actions (Liepmann & Maas, 1907 cit. in Heilman & Rothi, 1997). They also suggested that the sequencing deficit may be affecting both aphasia and apraxia. However, as pointed out previously, aphasia and apraxia can exist independently.

Apraxia has also been identified in patients with right hemisphere lesions (Maher & Ochipa, 1997). In this case, a left-handed patient was apraxic but not aphasic suggesting that the left hemisphere mediated language in this individual, but the right hemisphere was important for praxis. Poor gesture performance has been reported in left as well as in right brain dysfunction (Barbieri & De Renzi, 1988; Roy, Square-Storer, Hogg, & Adams 1991).

3.3.3. Two Stage Models

De Renzi (1985) posited a step that accounted for the semantic knowledge of familiar gestures within the praxis processing system (containing the long-term representations of learned gestures). He suggested that the left hemisphere was important for storing and retrieving gestural representations as well as storing features that define the object meaning. De Renzi (1985) added a second level to the model, one in which encompassed the motor control for a to-be executed action. Further, different patterns could emerge depending on the level of deficit. For example, a deficit at the first level (semantic impairment) would result in deficits in retrieving conceptual information; however the patients could still be able to imitate gestures without difficulty. This type of resulting pattern is an *ideational* apraxia and tasks assessing the production of meaningful gestures on command would be used to test for this apraxic syndrome.

Subsequently, a deficit at the second level would result in a different praxis pattern. Namely, the performance of tasks requiring gesture production would be affected, but the ability to identify and recognise gestures would be unaffected. According to De Renzi (1985) this pattern would correspond to an *ideomotor* apraxia. Therefore, a gesture imitation task would be used to assess this praxic syndrome and the author suggested that meaningless gestures are the most efficient gesture type to use when testing for this type of apraxia. De Renzi (1985) suggested that a deficit in the imitation of meaningless gestures results in an ideomotor apraxia, whilst a deficit in gesture production to command and impairment in the imitation of meaningful gestures results in an ideational apraxia.

Historically, the original apraxia dichotomy only tested gesture production but not recognition or comprehension. In 1985, Roy and Square posited that the praxis system was made up of two components; a conceptual and production system. The authors suggested that the *conceptual* system (top-down model) included three kinds of knowledge: knowledge of objects and their functions; action knowledge; and knowledge of the seriation of single actions. The *production*

system is important in the actual motor control of skilled movement. The authors hypothesised that disruptions in each of these systems may be associated with a unique error pattern of movement. For example, a recognition error may arise for different reasons – perceptual or functional similarity of objects, or spatial proximity.

This two-stage model lends itself to different predictions. Impaired pantomime production with preserved imitation performance would correspond to a deficit in the selection of an action from long-term memory (i.e., ideation); the second pattern, impaired imitation without any other noted deficits, would correspond to a deficit in visual gestural analysis or translating the information into a movement; and the third pattern of impaired pantomime and imitation would reflect a disturbance in the executive stage of gesture production (Heath et al., 2001).

3.3.4 Disconnection Hypothesis of Apraxia

Geschwind (1965) proposed that language elicits motor production using the same neural circuitry as Wernicke suggested for speech. He posited a hypothesis implicating a language and motor disconnection. Stimuli for production of a pantomime to verbal command requires "information to flow sequentially" along the auditory pathway to the Heschl's gyrus (primary auditory cortex) and from there, the auditory signal is sent to the temporal lobe (auditory association cortex: Rothi, Ochipa, & Heilman, 1991, p. 444). This area of the temporal lobe is known as Wernicke's area in the left hemisphere and it is important for language comprehension (Rothi et al., 1991). The arcuate fasciculus connects the motor association cortex to Wernicke's area. The left motor association area and the left primary motor area are also connected. This is the pathway that is used when producing a gesture to verbal command with the right hand. However, to make the same production with the left hand, the information must first be relayed to the right motor association cortex and then to the right-sided motor areas. Therefore, a disruption to the pathways connecting the motor association areas would in fact,

explain most apraxic disturbances according to Geschwind's theory (see Heilman & Rothi, 1993, for review).

Subsequently, various patterns of apraxia emerged depending on the area of disconnection. For example, when the left motor association region was disconnected from the right, as in cases of callosal apraxia, a unilateral *ideomotor* apraxia ensued. When the arcuate fasciculus was disconnected, the Wernicke's area was not able to communicate with the motor association cortex (e.g. a patient would be able to comprehend a verbal command but not be able to produce the gesture: Rothi & Heilman, 1997). Conversely, more posterior lesions, affecting Wernicke's area would result in patients with verbal comprehension deficits without apraxic disturbances; subsequently, they would fail in tasks of gesture production secondary to comprehension deficits (Heilman & Rothi, 1993).

As more cases of apraxia were identified, Geschwind's hypothesis failed to explain specific patterns. Theoretically, patients with lesions to the arcuate fasciculus should have been able to imitate because the verbal comprehension component of the gesture production was bypassed; however, many of the patients failed in tasks of imitation (Heilman & Rothi, 1993). Over the years, researchers continued to try to account for various patterns of performance identified in patients with limb apraxia using various models of praxis processing.

3.4 DEVELOPMENT OF MODELS OF PRAXIS PROCESSING

3.4.1 Representational Model

Clearly, the classic dichotomy of ideomotor/ideational apraxia is not sufficient in explaining all of the dissociations reported in gesture production and imitation tasks in patients with limb apraxia. Moreover, the interpretation of ideational and ideomotor apraxia according to Liepmann suggests that limb apraxia must be considered as a production deficit (Bartolo, Cubelli, & Della Sala, 2008; Cubelli

& Della Sala, 1996).

As an alternative to the Geschwind hypothesis (1965), Heilman and Rothi (1993) posited a *representational hypothesis*. Heilman, Rothi, and Valenstein (1982) suggested that there were “similarities between how the brain processes language and how the brain processes praxis” and compared the gestural processing system to the modular processing systems of aphasia. After describing dissociations in gesture performance of apraxic patients with left anterior lesions versus patients with left parietal lobe lesions, and defining the differences in patterns of performance in tasks of gestural comprehension and production, the authors suggested that this dichotomy in ideomotor apraxia was evidence of two different types of ideomotor apraxia resulting after different lesions. The first, resulted after destruction of the praxicons in the left parietal lobe, presenting with patients with poor discrimination, comprehension deficits, and impairment of gesture production to command. The second, resulted from the disconnection of these praxicons from the innervatory formulas for action. The authors suggested that if the engrams are intact, but disconnected from the motor area, the patients should be able to discriminate and comprehend gestures, although both types of patients would demonstrate difficulty using objects, producing gesture to command, and imitating (Rothi, Ochipa, & Heilman, 1997). The authors suggested that these findings supported Liepmann’s theory of “movement formulae” and innervatory spatiotemporal representations or *praxicons* that were stored in the left parietal lobe.

3.4.2 Model of Praxis Processing of Rothi, Ochipa, and Heilman (1991)

The apraxia theories up to this point could not account for modality-specific dissociations observed in patients such as the patient described by Ochipa, Rothi, and Heilman (1994) whose performance on pantomime to imitation was worse than his ability to pantomime to verbal command in the presence of spared

reception. To account for this selective impairment, a model was designed to separate the representations for gesture production and gesture reception. The authors proposed a dual route model of praxis processing that included a route for the processing of meaningful gestures (that pass through the long term memory system storing the shape of all familiar gestures), and a direct route that allowed for the imitation of meaningless gestures (from perception to action). This model marked a turning point in the understanding of gestural processing because it was the first model to evaluate both the comprehension and production of the gestures. The dual-route allowed for two separate processes; the meaningful gestures were processed along the semantic or 'lexical' route and the meaningless gestures were processed along the 'non-lexical' route (Cubelli et al., 2000; Rothi et al., 1991). See Fig. 3.6 for a diagram of the neuropsychological model of praxis processing.

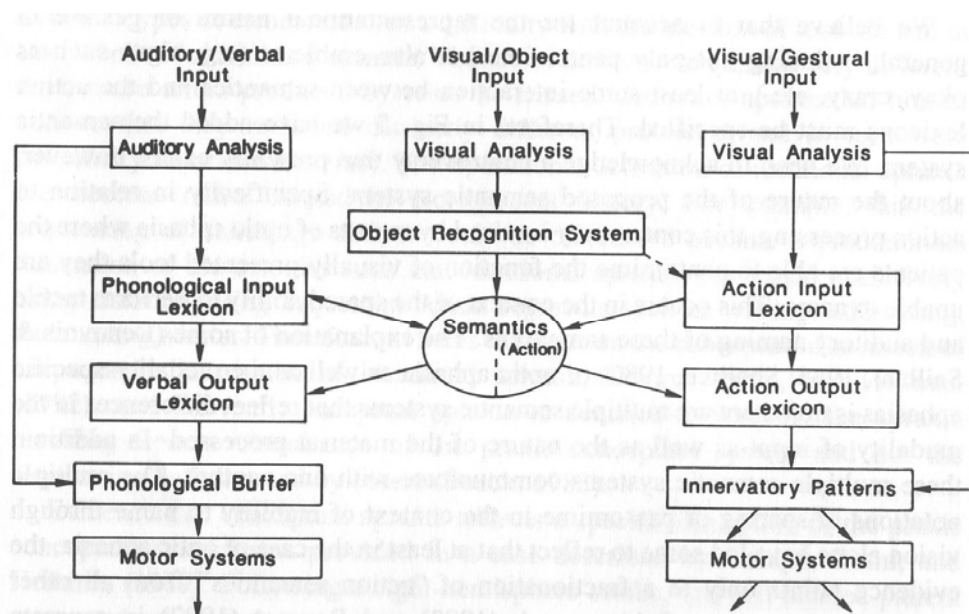


Figure 3.6. Rothi, L.G., Ochipa, C., & Heilman, K.M. (1991). A cognitive neuropsychological model of limb praxis. *Cognitive Neuropsychology*, p. 457.

In line with the lexicon in language models, the lexicon in the praxis model was based on the concept that there is a processing advantage for previous movements. Therefore, to account for the pattern of performance of spared pantomime

production in the presence of impaired pantomime imitation and spared reception, the authors considered that this might be similar to dissociations of word recognition and word production in language processing models and that was the theoretical underpinning justifying the inclusion of input and output gestural processing (Rothi et al., 1991; 1997). The authors posited that the action lexicon would be analogous to the “movement memories” (Rothi et al., 1997). The lexicon was further broken down into two different stages: The input action-lexicon (e.g., stored information about perceived actions) and the output action-lexicon (e.g., movement formulae or time space representations). Therefore, explaining the case of intact gesture reception, the authors suggested that the deficit would have to occur at some point after the input action-lexicon.

Not only had cases been identified demonstrating dissociations in reception versus production (Ochipa, Rothi, & Heilman, 1989); production versus imitation (Ochipa, Rothi, & Heilman, 1994); and meaningful and meaningless gestures (Rothi, Mack, & Heilman, 1986), but selective impairments in gesture processing dependent upon input modality had also been identified (De Renzi, 1985). As these case studies of patients with apraxia began to be identified, the apraxia model was modified (Rothi, Ochipa, & Heilman, 1991) to include separate stimuli of auditory/verbal; visual/gestural; and visual/objects input modalities (see Fig. 2.7).

Although the model was instrumental in describing the complex architecture of the praxis system, the components were founded on anatomical concepts, including the “innervatory patterns” based on Liepmann’s descriptions as well as the supplementary motor area (SMA: Rothi et al., 1991, p. 447) that is not well-understood (Luders, 1996, cit. in Cubelli et al., 2000).

3.5 COGNITIVE MODEL OF PRAXIS PROCESSING

3.5.1 Introduction

In 2000, Cubelli and colleagues modified Rothi et al.'s (1991) model, thereby creating a complete cognitive model of praxis processing (Cubelli et al., 2000). It is a top-down model allowing predictions to be made of cognitive impairment based on gesture performance at each level of evaluation. The model assesses both comprehension and production of gestures as well as incorporates a dual-route system, (two separate processes), to evaluate gestural processing along the semantic or 'lexical' route for meaningful gestures and along the 'non-lexical' route to process meaningless gestures (Cubelli et al., 2000). The model differs from the previous model in three main areas:

1. It includes a visuo-conversion mechanism responsible for production of meaningless gestures by “transcoding visual information into motor programs” (Cubelli et al., 2000, p. 148).
2. There is no assumption of a direct link between the input and the output lexicon.
3. The model includes an additional gestural memory buffer, equivalent to the phonological buffer in language models, that “holds a short-term representation of the to-be-executed motor program” (Cubelli et al., 2000, p. 148). See Fig. 3.7 to view the cognitive model of praxis processing.

3.5.2 Cognitive Components of the Model

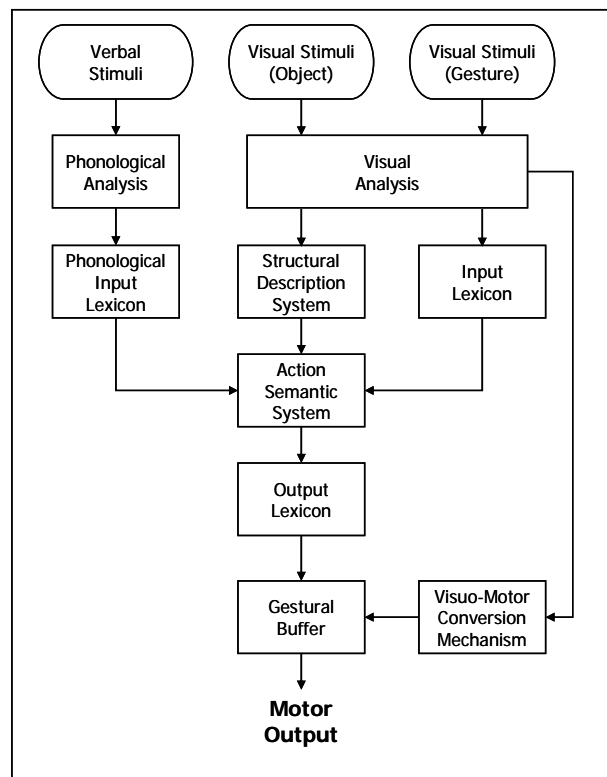


Figure 3.7. Cognitive model of praxis processing (Cubelli et al., 2000).

Input Modality

The cognitive model of Cubelli et al. (2000) tests the gestures across multiple modalities including visual stimuli for objects and gestures, and verbal stimuli.

Action Lexicon

Similar to word recognition and word production in language processing models; the processes which access the gestural lexicon can be divided into two stages: the *input* action-lexicon and the *output* action-lexicon (Cubelli et al., 2000). As in the lexicon of language models, the lexicon in the cognitive model is based on the

concept that there is a processing advantage for previously seen movements. The ‘form’ or representation of these gestures is stored in the long-term memory system of the gestural lexicon and therefore allows for gesture recognition. The *output* lexicon contains the procedural gestural knowledge and allows for production of all known gestures (Bartolo et al., 2003).

The *production* component of the model contains the procedural knowledge of the action. Importantly, action requires the integration and coordination of both components; the conceptual *and* procedural knowledge held in the action semantic and action output respectively (Bartolo, et al., 2003; Rothi et al., 1991; 1997).

This is the difference between ‘knowing’ how an object should be used and actually having the recipe to use it. In everyday life we may know how an object should be used although we have no experience using it (e.g., knowing how a kite should be used but not possessing the instructions to fly the kite: Bartolo, 2002; Bartolo et al., 2003).

Action Semantics

Just as the ‘form’ is stored in long-term memory, the content of familiar gestures is stored in a second long-term memory system of the action semantic system. (Rothi et al. (1991) also added an action semantic component to their model based on Roy and Square’s (1985) two stage models of praxis processing. As discussed in the two stage model of apraxia, Roy and Square (1985) suggested that the *conceptual* system (top-down model) included three kinds of knowledge: knowledge of objects and their functions; action knowledge; and knowledge of the sequencing of single actions. In addition to action knowledge, the semantic system also holds gestural meaning for pantomimes (e.g., the mime of object use) and intransitive gestures (e.g., communicative gestures: Bartolo, 2002).

Visuomotor Conversion Mechanism

The visuomotor conversion mechanism makes up the non-lexical route and is responsible for transforming visual information into motor action. Goldenberg

and Hagmann (1997) suggested that impaired imitation of meaningless gestures must lie somewhere between perception and motor execution. In 1995, Goldenberg published his findings that apraxic patients demonstrated difficulty performing gestures on themselves and also had difficulty performing gestures on a manikin. These findings led Goldenberg (1995) to suggest that impaired imitation in apraxic patients is the result of "the inability to translate a correct concept of the intended movement into an appropriate motor act" (Goldenberg, 1995, p. 72).

Gestural Buffer

The gestural buffer is similar to the phonological buffer in language models. The gestural buffer holds the motor programs for both the lexical and non-lexical routes until the gestures are executed. It is the gestural buffer that allows for the time necessary to translate the abstract formations of gestures into accurate and timely sequences of motor commands necessary for "linked movement segments" resulting in visible action (Cubelli et al., 2000, p. 147).

3.5.3 Possible Clinical Profiles of Apraxia Based on the Model

Based on the components of the cognitive model (Cubelli et al., 2000), five predictions can be made depending on the level of breakdown in the gestural system:

1. Deficit of the Action Input Lexicon: A patient with a deficit at the level of the action input lexicon would present with difficulty discriminating seen gestures coupled with a spared ability to execute gestures to verbal command and on imitation (using non-lexical route). There are cases in the literature of patients (pantomime agnosia) who could not discriminate or comprehend visually presented gestures but could perform these same gestures

on command. The *verbal* route was spared and they could produce the gesture. Dissociations of processing along the different modalities have been reported.

According to the model, all familiar gestures, once recognised at the level of the input lexicon, are processed via the lexical route, and all unfamiliar gestures are processed via the non-lexical route. Therefore, if gestures are not recognised, they are considered unfamiliar even if they are meaningful and would therefore be processed down the non-lexical route. This profile would be similar to patients who have been identified with pantomime agnosia (Rothi et al., 1986).

2. Deficit of the Action Semantic: A deficit at the level of the action semantic system would be characterised by impaired execution of meaningful gestures, coupled with spared imitation of meaningless gestures. Patients would demonstrate difficulty attributing meaning to gestures; however, they would be able to discriminate familiar from unfamiliar gestures because the ability to recognise and discriminate gestures is stored in the input lexicon.

3. Deficit of the Action Output Lexicon: A deficit at the level of the action output lexicon would result in a pattern of praxis processing characterised by a deficit in the production of meaningful gestures but with an unimpaired ability to comprehend and attribute meaning to gestures. A deficit at this level differs from a deficit at the level of the action semantic in that the meaning is spared but the patients demonstrate difficulty in the production of meaningful gestures. With access to the spared visuo-conversion mechanism, the imitation of meaningless gestures would be normal.

4. Deficit of the visuo-motor conversion mechanism: A deficit at this level would present as an isolated impairment in the imitation of meaningless gestures, but comprehension and production of meaningful gestures would be unimpaired. This would be considered an ideomotor without ideational apraxia (Bartolo et al., 2001).

5. Deficit of the Gestural Buffer: Finally, a deficit at the level of the gestural buffer would impair all execution tasks whether they were meaningless or meaningful or presented on command or imitation. However, the ability to perform tasks of recognition and comprehension would be unaffected. This clinical picture would result in both ideational and ideomotor apraxia.

It is important to note that the predicted patterns are compatible with Rothi et al.'s original model (1991). However, the modified version of the model uses only cognitive concepts.

3.6 TESTING THE COGNITIVE MODEL OF APRAXIA

Bartolo, Cubelli, and Della Sala (2008) recently published their findings of a series of studies evaluating gesture in limb apraxia patients. The authors administered a new battery of tasks specifically designed to assess the different levels of praxis processing based on the model of Cubelli et al. (2000). The battery was composed of thirteen different tasks designed to evaluate the lexical and non-lexical routes of the model as well as the input and output systems. Eight tasks tested the production of meaningful gestures (e.g., to command and imitation); four tasks evaluated the ability to recognise gestures, and one task assessed the imitation of meaningless gestures. See Fig. 3.8 for an example taken from the Apraxia Battery administered by Bartolo (2002).

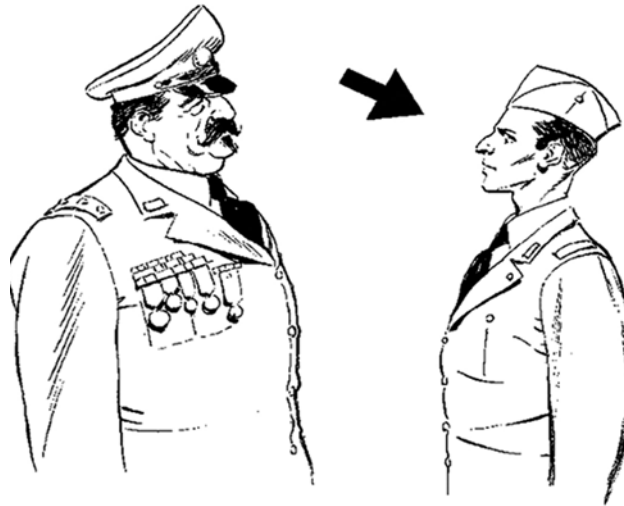


Figure 3.8. Example of stimuli designed to elicit an intransitive gesture (Bartolo et al., 2008).

Following the administration of the tasks to healthy volunteers, the battery was administered to patients with brain damage (Bartolo, Cubelli, Della Sala, Drei, & Marchetti, 2001; Bartolo, 2002; Bartolo et al., 2003). The results indicated that the healthy participants found pantomimes to be more difficult to perform than the other gestures. Moreover, it was determined that the administration of the battery was successful in identifying dissociations in gestural processing that may have otherwise gone undetected. The application of this instrument to patients with brain lesions was also successful in identifying patterns of praxis processing.

3.6.1 Meaningful and Meaningless Gesture Dissociation

One of the dissociations identified using the apraxia battery was the selective impairment in the imitation of meaningful versus meaningless gestures (Bartolo et al., 2001). Three patients with left ischaemic strokes (i.e., temporo-parietal, subcortical, and fronto-temporo-parietal lesions) were selected from the apraxia study and their results compared to twenty healthy participants. A battery of tasks

was designed to assess gestural processing of transitive and intransitive gestures including recognition, identification, and production. All three participants performed within the normal range on the tasks of recognition and identification. However, two patients showed a selective deficit in the imitation of meaningless gestures. Conversely, patient MF, demonstrated a different pattern, namely, a selective deficit in the production of meaningful gestures. The authors suggested that according to dual-route models of praxis processing, the non-lexical route ought to be spared since the imitation of meaningless gestures were performed without difficulty. Therefore, the deficit should occur along the lexical route of gestural processing. MF did not demonstrate any difficulty discriminating or comprehending gestures; therefore, the deficit occurred at the level after comprehension thereby disrupting accurate gesture production of meaningful gestures.

3.6.2 List Effects

The dissociation of performance of meaningful and meaningless gesture imitation suggests that the imitation of different types of gestures may be subserved by different cognitive systems (Bartolo et al., 2001; Goldenberg & Hagmann, 1997). Meaningless gestures require different cognitive processes to perform than meaningful gestures, and performance of meaningless gestures depends on the testing method. This phenomenon has been referred to as a “list composition effect” (Cubelli, Bartolo, Nichelli, & Della Sala, 2006, p. 118).

Cubelli et al. (2006) tested 23 left-hemisphere damaged patients in tasks using pure (i.e., only meaningless gestures included) and mixed lists (i.e., meaningful and meaningless gestures intertwined in the same list). They found that patients performed better when pure lists were administered than in tasks using mixed lists, suggesting that the use of pure lists “compels gestural processing along the appropriate route” (p. 119). Moreover, the patients did not shift from one route to another in tasks of mixed lists but would use one route at a time recruiting the

least damaged route to produce the gesture. The authors suggested that the use of pure lists are beneficial when diagnosing imitation deficits in apraxia whereas the use of mixed lists may be helpful in identifying the strategic use of gestural processing routes in the imitation of meaningful and meaningless gestures.

Others have also tested list composition effects in both healthy participants and patients with brain damage. Tessari and Rumati (2004) tested the strategic use of gestural processing during imitation in a dual route model although they tested healthy participants. Administering tasks in single blocks (pure lists) and mixed lists, they found that participants performed better in tasks of meaningful gestures than in meaningless gestures in the single block design but in the mixed list task, there were not any significant differences between meaningful and meaningless gesture imitation. The authors hypothesised that when meaningful gestures are tested separately, the gestures are easily recognised by the participants and the information from long term semantic memory is then retrieved and the gestures are reproduced. However, when meaningless gestures are presented in blocks, the semantic memory is not recruited and the participant must rely on direct imitation in order to reproduce the gesture. Conversely, when meaningless and meaningful gestures are tested together in a mixed list design, the authors suggested that only one process would be used in reproducing both gesture types to minimise the cost of switching between processing routes and purported that the non-lexical route would be recruited in mixed lists.

3.7 GOLDENBERG AND MEANINGLESS GESTURES

A patient may display impairments in the production of meaningless gestures whilst the production of meaningful gestures is spared (Goldenberg & Hagmann, 1997). Impairment in the production of meaningless gestures with spared meaningful gesture production has been termed visuoimitative apraxia (Goldenberg & Hagmann, 1997). In their 1997 study, Goldenberg and Hagmann found that patients with left parietal lesions made errors when imitating

meaningless gestures, but not when performing meaningful gestures to imitation or to verbal command. They suggested that these findings provided support for a direct route to action and argued that their findings provided evidence against an explanatory theory of motor disturbances interfering with imitation in patients with left brain damage. The authors explained that if motor disturbances were the sole explanation of the imitation impairment in patients with brain damage, then equal performance of imitation and production of gestures retrieved from long term memory should be observed as well as equal imitative disturbances in the imitation of meaningful and meaningless gestures (Goldenberg & Hagmann, 1997).

Goldenberg (1999), reported findings that patients with damage to the left inferior parietal lobe experienced deficits in performing hand imitation tasks whilst patients with right inferior parietal lobe damage demonstrated deficits in tasks assessing finger imitation. The author suggested that the imitative performance was based on damage to different underlying processes; namely that patients with right brain damage (RBD) experienced deficits in visuospatial abilities necessary to discriminate and produce finger positions, and patients with left brain damage (LBD) experienced impairments in 'body part coding'. Goldenberg (1999) proposed a model that included a common code, linking perception and production of gestures, and incorporating body part knowledge and spatial relationships (see also Goldenberg & Karnath, 2006). See Fig. 3.9 for examples of hand and finger imitation and matching tasks.

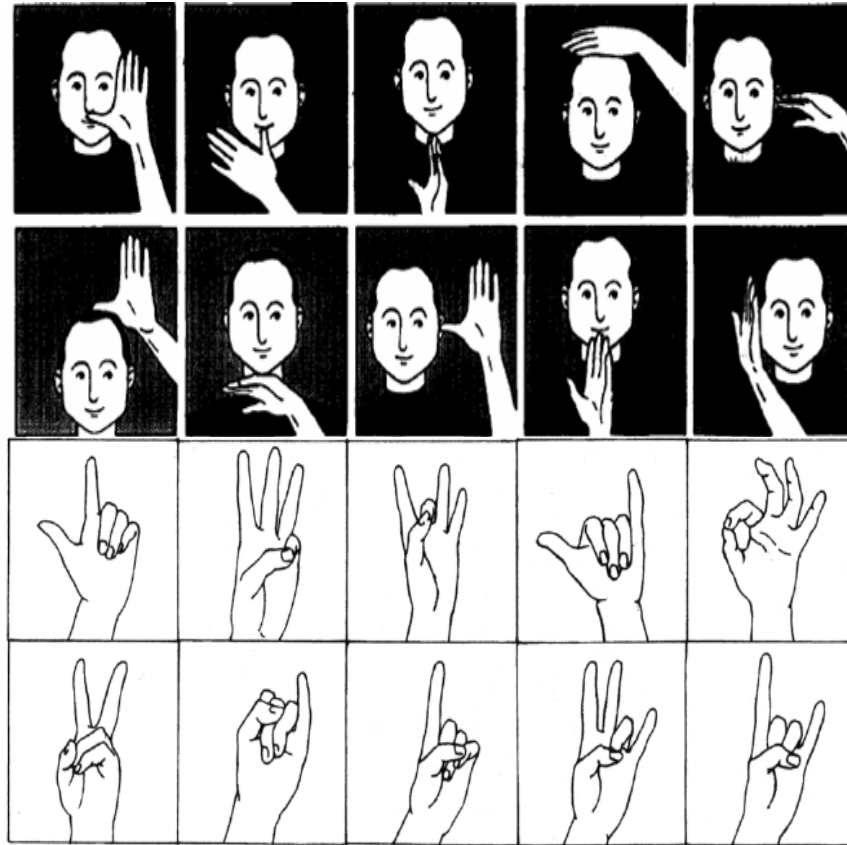


Figure.3.9. Hand and finger positions. Goldenberg, G. (1999). Matching and imitation of hand and finger postures in patients with damage in the right or left hemispheres. Neuropsychologia, 559-566.

To further evaluate the dissociation in the imitation of meaningless gestures, Goldenberg investigated the performance of participants in two tasks: gesture imitation and gesture matching. He found that the patients with right brain damage demonstrated difficulty with the matching task and the patients with left brain damage showed greater impairments in the imitation task, specially hand postures. Goldenberg supported this finding by describing the differences in the necessary abilities required to perform tasks of imitation and matching.

Goldenberg suggested that imitation requires mapping from one person to another from different spatial positions, taking into consideration the differences in the physical attributes of the body such as size, height, shape (Goldenberg &

Hermisdorfer, 2002). 'Coding' involves translating these features using the concept of the human body and the boundaries that define it (Goldman & Hagman, 1997). In tests of limb apraxia, meaningless gestures are tested in imitation modality because it is difficult to describe the actions verbally.

3.8 ACQUIRED APRAXIA VERSUS DEVELOPMENTAL DYSPRAXIA

Deficits in praxis processing have been reported in both adult and paediatric patient populations (referred to as “dyspraxia”, Cermak, Gubbay, & Larkin, 2002; Dewey, 1995; Sanger et al., 2006). Whilst limb apraxia results after acquired neurological left-sided brain damage (Cubelli et al., 2000; De Renzi & Faglioni, 1999), dyspraxia in developmental populations may result without any observable brain lesion. In adults, the ability to perform previously learned gestures is impaired (Bartolo et al., 2008; Cubelli et al., 2000; De Renzi & Faglioni, 1999) but in children, it is the development of skilled motor functioning that is of major difficulty (Cermak, 1985, Cermak, Gubbay, & Larkin, 2002; Morris, 1997).

Initial studies of developmental dyspraxia evaluated dyspraxia in terms of adult apraxia etiologies (Orton, 1937); later, the pendulum swung in the opposite direction with studies considering dyspraxia in the context of paediatric brain development, apart from adult models (Finger & Stein, 1982 cit. in Cermak, 1985). Today, it appears that a balance has been reached with researchers suggesting that dyspraxia “may be associated with maturational processes in similar locations” as acquired adult apraxia (Sanger et al., 2006, p. 2164).

3.9 HISTORY OF DEVELOPMENTAL DYSPRAXIA

The study of developmental dyspraxia began in the early 1900's, around the same time that Liepmann published his findings of the case of the Civil Servant. Collier is often credited as being the first to publish his findings of the disorder, using the

term “congenital maladroitness” (Ford, 1966 cit. in Cermak, 1985).

Orton (1937) was the first to recognise and use the term developmental dyspraxia in children, and he described activities in which he observed that children were “clumsy” and “exceedingly slow” in their movement and development. He included developmental dyspraxia in his review of one of the six most common types of developmental disorders. In another parallel to adult apraxia research, Orton (1937) encouraged further study to investigate the differences in developmental apraxia distinguishing between two different types; sensory and motor. Similar to the separation between ideomotor apraxia and ideational apraxia, Orton described sensory apraxia as a comprehension deficit (not being able to understand the movement) and motor apraxia as a movement disorder (understanding the movement without the ability to execute the movement: Miyahara & Mobs, 1995).

It was not until the 1970s that more findings began being published on the topic of developmental dyspraxia; however, definitions differed across studies. Ayres (1972, cit. in Morris, 1997) defined developmental dyspraxia in terms of a sensory-integrative-based disorder and later identified three different types of sensory integration dyspraxia discussing the poor processing of sensory information including tactile, proprioception, visual, vestibular, and visuomotor (Ayres, 1989, cit. in Morris, 1997).

Gubbay (1975) suggested that both agnosia and apraxia are interdependent in tasks that require skilled movement, and therefore could be considered together in children demonstrating signs of clumsiness and incoordination. Moreover, he defined dyspraxia as a general clumsiness in the presence of intact neurological and cognitive functioning and suggested that clumsiness in children with low IQs could not be considered dyspraxia. The use of the word ‘clumsiness’ in developmental dyspraxia has often confounded the disorder with other types of disabilities, including children with coordination difficulties. It has also been suggested that apraxia is a disruption to a number of different processes: “a

conceptual/symbolic disorder, a disconnection between control centers in the brain, an impairment of the body schema, or a motor control disorder” (Roy et al., 1990, p. 363). Throughout the years, the study of developmental dyspraxia has evolved, but to date there is still not a universal definition or description defining the disorder.

3.10 THE NEED TO APPLY ADULT MODELS OF APRAXIA TO DEVELOPMENTAL DYSPRAXIA PAEDIATRIC POPULATIONS

Cermak (1985) pointed out that early tests of dyspraxia only included tests of nonrepresentational (e.g., meaningless) gestures and stressed the importance of the inclusion of both representational and nonrepresentational gestures (e.g., meaningful and meaningless gestures) in assessments when testing children. Another problem she highlighted was that developmental dyspraxia was often viewed in terms of a unitary disorder in children differing from adult apraxia where various apraxia types have been identified.

After reviewing the typology of apraxia as either a planning or executive disorder, as outlined by Roy (1978), the author adopted the same approach to investigate dyspraxia in children. Cermak (1985) observed that not all previous dyspraxia researchers had determined if the level of breakdown was at the conceptual or execution stage in the children they had tested. However, Ayres (1972, cit. in Morris, 1997) identified planning difficulties and general organisation problems in children with dyspraxia within the sensory integration theory and Cermak (1985) discussed the similarities between the planning disorder described by Ayres (1972) and a primary planning disorder of Roy (1978); comparing the adult and developmental dyspraxia models. Finally, Cermak (1985) discussed the clumsy child and incoordinated child and suggested that this manifestation of knowing 'what to do' but not knowing 'how to' execute the plan may be similar to executive dyspraxia as described by Roy (1978, cit. in Cermak, 1985).

It suggests that the two share common symptomatology and behavioural manifestations. Certainly there is precedent in the usage of terms such as developmental dyslexia, developmental dysphasia, and developmental acalculia. The acceptance of the commonality of terminology allows further sharing of common findings from adult and childhood research, and an understanding of the commonalities and differences might well, in the future, lead to a more complete understanding of normal central nervous system development of function (Cermak 1985 p. 242).

Contemporary studies of dyspraxia in the paediatric populations now focus on the similarities between the two fields, borrowing from the rich neuropsychological research in adults to inform praxis processing in developmental disorders (Dewey, 1995). Importantly, studying praxis in both acquired and developmental disorders is of benefit to both populations; adult models can be used to further our understanding of the breakdown of praxis in developmental dyspraxia, but also knowledge of praxis acquisition in developmental populations can inform our understanding of which systems depend on one other in development (Rothi & Heilman, 1997). Therefore, this thesis follows the definition of dyspraxia reported by Dewey and colleagues that follows a developmental neuropsychological approach, defining dyspraxia as a disorder in gestural performance resulting in deficits in representational (e.g., meaningful) gestures; nonrepresentational (e.g., imitation of meaningless gestures); and gestural sequences (Dewey, 1995; Dewey, Cantell, & Crawford, 2007).

In 1985 Cermak reviewed previous research in developmental dyspraxia and observed that the performance of different parameters were not being tested in children in the same way as they were in adults. Understandably, children are still developing, but whilst adults may be assessed in terms of pathological and nonpathological performance, children's praxis skills need to consider modality-specific developmental standards. Cermak (1985) stressed the importance of developing a psychometric tool to assess developmental norms of praxis

processing across age ranges. To date, there still has not been a tool specifically designed and calibrated to measure praxis processing in developmental populations.

3.11 'CLUES' FOR NEUROPSYCHOLOGICAL EVIDENCE OF DYSPRAXIA IN AUTISM

The observation that individuals with autism experience difficulty producing gestures has been reported since the time of Kanner. Kanner (1943) published his report of a child from his original research describing, “Her expression was blank, though not unintelligent, and there was no communicative gestures” (p. 240). Asperger (1944) also reported his observations that his patients moved in a ‘clumsy way’. In another early report, greater than one third of a group of autistic children were described as ‘clumsy’ and demonstrated difficulty performing conventional and organised movements (Wing, 1969 cit. in Jones & Prior, 1985).

Although similar gesture types have been tested in individuals with autism as in patients with limb apraxia, comparison of autism studies with praxis processing research in adults is not straightforward. Fortunately, many of the autism imitation studies left ‘clues’ behind in their discussions and interpretations of findings that encouraged further research into the study of the neuropsychology of dyspraxia.

Gestures can be divided into two main categories; meaningful, those containing representations in long-term memory; and meaningless, those gestures that are non-symbolic and therefore do not contain any meaning (e.g., opening and closing fist). Transitive gestures, pantomimes, intransitive gestures, and meaningless gestures have all been tested in individuals with autism. Similarly to the terminology inconsistencies impeding gesture comparison of imitation studies, apraxia terminology in autism studies is often confusing with a “lack of consensus concerning the best definition of the disorder” (Dewey, 1995, p. 254). The autism literature describes deficits in motor coordination, limb apraxia,

manual dyspraxia, ideomotor apraxia, and oral apraxia (Cermak, 1985; Dewey, 1995). The following section will highlight the relevant autism studies according to the aforementioned neuropsychological definitions. These current studies are in addition to the imitation findings reviewed in the previous chapter. In an attempt to categorise the gestures following adult apraxia research, similar gesture types will be reviewed for easier comparison. Here, discussions of dyspraxia taken from these autism and imitation studies will be discussed to address the broader question of an underlying deficit in praxis processing in ASD.

3.11.1 Dyspraxia ‘Clues’ from Studies of Meaningless Gestures in Autism

Many of the imitation studies in autism utilised two different assessments and included meaningless gestures, the Uzgiris-Hunt and the Berges-Lezine. Five meaningless gesture imitation studies will now be reviewed with an emphasis on apraxia theory.

In the 1970s, DeMyer and colleagues published one of the earliest accounts of an imitation deficit in autism. The authors hypothesised that autistic and schizophrenic children showed a “specific pattern of imitation deficits” and that they appeared to differ in their imitation performance when compared to ‘subnormal’ children (DeMyer et al., 1972, p. 265). The pattern that they predicted was that autistic and schizophrenic children would imitate actions with objects better than body imitation actions. The tasks for body imitation comprised meaningless hand and finger tasks (e.g., close fist, wiggle thumb) as well as whole body imitations (e.g., walk heel-to-toe). The motor-object imitation tasks tested coordination and motor skills (e.g., walk board raised 1 foot on 1 foot off). Although the study included schizophrenic children and meaningless hand and finger imitations were combined together with body imitation, the study was important, and raised theoretical questions, thereby setting the stage for future

studies.

The authors suggested that the motor programs necessary for gesture imitation appeared to be intact because the children performed better when they used objects than when they performed body imitation. They argued that there appeared to be a deficiency in integrative function between the motor and sensory systems and transferring the gestures via visual memory to body parts appeared to be disrupted. A child must have a “clear idea that his body is like the body of another. If he does not know this, his so-called body image is defective which would be a special agnosia of body parts leading to a *motor imitative dyspraxia*” (DeMyer et al., 1972 p. 281). The authors compared the performance of the children to adult patients. The adults had demonstrated deficits performing actions with objects when the objects were out of sight. The authors attributed the imitative deficit to deficits in either body part agnosia, visual memory, or both.

Researchers today are still interested in the concept of sensory and motor integration. In apraxia research, a component of praxis processing models includes a visuomotor conversion mechanism responsible for transcoding visual information into motor programs (Bartolo et al., 2003; Cubelli et al., 2000). Goldenberg (1999) suggested that deficits in body part coding and mapping from one person to another can affect meaningless gesture imitation in adults with brain damage.

In another study providing evidence of dyspraxia in autism, Jones and Prior (1985) tested body imitation in ten autistic children and found that when compared with two different control groups, (one matched for language and the other for chronological age), the children with autism performed more poorly in tasks of body imitation in imitation of simple hand and arm gestures, as well as in tasks measuring dynamic body movements. The tasks for the hand and arm were taken from Berges and Lezine (1965) and were meaningless gestures. The authors cited earlier studies that interpreted the lack of gestural use in communication as a lack of communicative intent or even withdrawal of the autistic child. Disagreeing with

this stance, they argued that the gestural deficits may be related to an imitation deficit that impedes the initial learning of the gestures. At the time of the study, imitation studies in autism were 'scarce'. The biological nature of autism was beginning to be acknowledged and the authors suggested that neurological 'soft signs' may provide support for the "influence of biological factors in the genesis of the disorder" (p. 38). Hand and arm imitation tasks requiring knowledge of one's own body were used.

The authors ruled out the possibility of a visual memory deficit affecting the performance because the imitation model was visible throughout the imitation experiment. Therefore, they argued, that a more plausible explanation appeared to be "inadequate neuromotor development" and not problems with body image (Jones & Prior, 1985, p. 43). They agreed with DeMyer and colleagues that the deficit appeared to be one of motor dyspraxia and not of symbolic representation. In addition, the presence of 'soft signs' in their autism sample pointed to central nervous system dysfunction. They recommended further study. It is important to note that although the authors suggested that the use of the visual model ruled out visual memory deficits, this does not address the issue of visual perceptual difficulties in autism.

Ohta (1987) tested hand and finger movements and T signs in his imitation assessment (see Fig. 3.10). The hand and finger imitation tasks evaluated four different gestures (i.e., holding pointer finger up; making a V sign; waving with the open palm; and giving "bull's horns" sign).

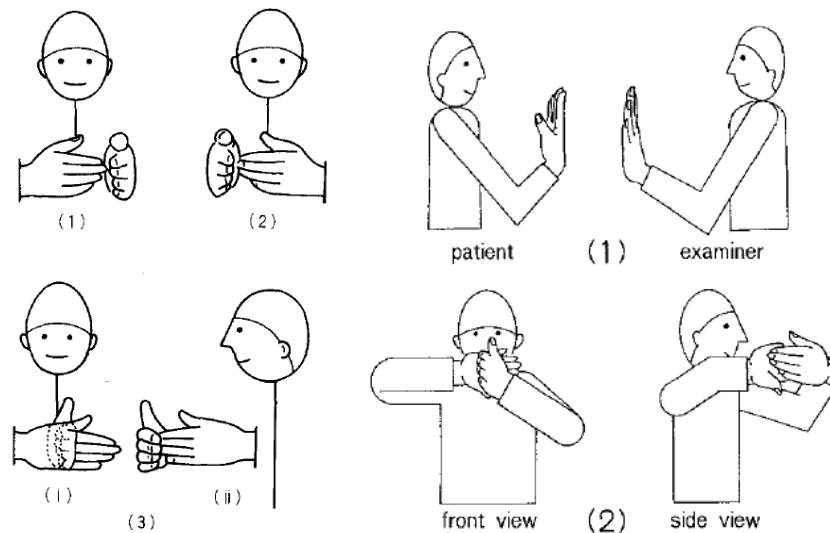


Figure 3.10. Examples of T signs taken from the Gesture Imitation Test as reported in Ohta, 1987 on the left and examples of partial imitations on the right.

The T signs were originally designed by Luria (1970). Ohta (1987) cited Bergees and Lezine (1965)'s report that two important factors come into play during imitation: perception and motor abilities. In perception, "the visual factors are the major components that correspond to the image of the body and correlate with the image of the outer world and bodies of others" (Ohta, 1987 p. 60). Luria (1970) tested brain damaged patients and suggested that a disturbance of visual cognition affected task performance (Luria, 1970 cit. in Ohta, 1987). The autistic participants that Ohta tested not only showed imitation deficits, but also demonstrated 'partial imitation' described as an imitation of only 'part' of a gesture. This was the first reported finding of this interesting error pattern in an autism group and was considered to be a *disorder* of gesture imitation and not a delay. The errors could not be attributed to IQ and therefore appeared to be autism-unique.

Ohta suggested that visual perception played a major role in the imitation deficits observed in the autism group and that dyspraxia played a minor role, and that a body image disorder was evident. He explained that the autistic children did not view the body parts together as one whole but rather, as pieces or individual units.

Ohta cited Berge and Lezine (1965) who suggested that two different groups emerged based on patterns of deficits during imitation tasks in children with developmental disorders; a perceptual group and a praxis group. Following the previous two reviewed studies (DeMyer et al., 1972; Jones & Prior, 1985) the integration of sensory and motor systems was implicated in the imitation deficits observed in autism. Ohta (1987) also suggested that deficits in spatial relationships and a disorder of mental image in tasks of body imitation, pointed to problems in symbolic representation and not motor deficits. Further investigation of spatial relationships and visual perceptions in autism was proposed.

Smith and Bryson (1998) tested imitation of non-symbolic postures and sequences in 20 autistic children and compared their performance to 20 children with language impairment and 20 typically developing children. Pictorial stimuli were used in tasks of gesture memory and gesture imitation. Gesture memory was assessed in the context of a recognition task and differed for postures and sequences. In the posture recognition task, the participants matched pictures and in the sequences task the participants were required to reconstruct the 2-action gesture sequences using two photographs. No group differences were evident in either task. In the gesture imitation task, significant group differences were revealed and the gesture performance findings could not be accounted for by memory or language delays. The authors also evaluated the error codes that included errors of form, left-right reversal errors, symmetry, and 180 degree rotation. Rotation errors of the hand were more common for autistic children. Rotation errors of Smith and Bryson (1998) are similar to those of Ohta (1987) except that they only included rotations of a full 180 degree rotation. The authors posited that the rotational errors observed in the autism participants may not indicate a deficit in visual ability, but rather may be indicative of a reliance on visual feedback as a compensatory mechanism. During the imitation attempts, the participants appeared to focus on what they could directly see in front of them. For example, if the participant were to see a palm of the hand in front of them, they would perform the imitation trial whilst looking at their own palm thereby resulting in a 180 degree rotation gesture imitation.

The authors purported that this finding may be a reflection of a deficit in integrating representations across modalities. Motor coordination difficulties were also noted in the group, but could not account for the imitative performance in their sample. Smith & Bryson (1998) suggested that further study in action-sequencing tasks were needed in autism that were similar to tests administered to patients with left and right brain damage.

In order to provide an adequate account of what is typical in autism, a well-articulated neuropsychological account of the normal development of praxic abilities is required (cf. Cermak, 1985, Dewey, 1995, Roy et al., 1990). Further empirical evidence of the disruption of praxis in autism would, in turn, assist the effort of constructing useful developmental models, both normal and pathological (Smith & Bryson, 1998, p. 766).

Page & Boucher (1998) published their findings of oromotor, manual, and gross motor skills in 33 children from a special needs school for autism. Hand skills were assessed using bimanual handshaping and positioning, three tests of unimanual shaping and positioning, and a sequencing task of handshaping. The bimanual handshaping gesture was tested within therapy sessions using the sign for “more” and the children had all been exposed to the sign in previous treatment sessions. The unimanual handshaping task consisted of various hand positions (meaningless) that were modeled and then imitated by the child. Finally, the manual skills were tested within everyday activities using common objects. The authors found that the rates of motor impairments were high with 80% of the children demonstrating impairment in at least one of the tested areas. Oromotor and manual impairments were greater than gross motor skills and 55% of the children had marked impairments of manual skills. Following previous suggestions of limb apraxia in autism (Rapin, 1996; Seal & Bonvillian, 1997), the authors predicted that the children with fine motor deficits would also present with

signs of dyspraxia including groping behaviours, partial representations (i.e., partial responses), and slow initiations. Whilst these signs were evident and may be reflective of an underlying dyspraxia, the authors also cautioned that the deficits could be related to imitation deficits or an underlying neuromuscular problem and that further testing of dyspraxia was warranted.

Stone, Ousley, & Littleford (1997) conducted a two-part study assessing different types of imitation and the relationships among imitation and other developmental skills. In the first study, the children were under three and a half years of age and consisted of three groups: 18 children with autism, 18 with developmental delay, and 18 typically developing children. The Motor Imitation Scale (MIS) was administered, and included 16 tasks (4 meaningful actions with objects; 4 meaningless actions with objects; and 8 body movements). It is important to note that six out of the eight 'body movements' were meaningless gestures (e.g., open and closed fist) and one of four of the meaningful actions with objects could possibly be considered meaningless (e.g., hold string of pop-beads behind neck). The four actions with objects were meaningless (e.g., bang spoon on table). The authors found that the autistic children demonstrated 'weaker' imitation skills than the comparison groups but that they followed the same overall performance pattern as the other groups. All groups performed better on the meaningful actions with objects than the meaningless actions and imitation of actions with objects was better than imitation of body movements.

In their second study, 26 two-year old autistic children were assessed and the relationship between imitation and developmental skills were evaluated (Stone et al., 1997). Object imitation was associated with later play skills and body imitation skills at age 2 were associated with expressive language skills one year later. The authors argued that these findings lend support for the presence of representational demands that are inherent in body imitation, "It is possible that the higher level of representation required for imitation of body movements may account for its closer link to language" p. 482). Although representational skills may indeed be recruited in tasks of gesture imitation (DeMyer et al., 1972; Smith

& Bryson, 1998); six out of the eight body movements tested were meaningless, and the association between nonsymbolic gesture imitation and language development is not clear. However, it is possible to discuss the meaningful gestures in light of the internal representations as suggested by Smith & Bryson, 1998; DeMyer, 1972).

The studies of Stone et al. (1990, 1997) contained a majority of meaningless gestures and the inclusion of the meaningless gestures may have influenced the end results in the MIS they administered.

In 2003, Rogers and colleagues tested 24 (34 months mean age) children with autism and compared their performance on various imitation tasks to 18 children with fragile X syndrome, 20 children with other types of developmental disorders, and 15 typically developing children. The authors made three predictions for the outcome of their study: 1) Imitation deficits would prove to be pervasive in autistic children, 2) Children with autism would perform better in tasks of actions with objects than other types of imitation would be associated with developmental areas, 3) Motor and social responsivity would demonstrate particular relationships with imitation in early autism.

The imitation battery consisted of 3 meaningless actions on objects (e.g., turn car upside down and pat it), 3 meaningless manual actions (e.g., pat elbow), and 3 oral-facial actions (e.g., extend tongue and wiggle sideways). Results revealed that all three subtests were highly correlated and the authors suggested that they were not independent of each other and subsequently combined the three scores into one total imitation score. Children with autism performed more poorly than the typically developing (TD) and the developmentally delayed (DD) group and were more impaired in tasks of oral facial and object imitation than in manual imitation. However, only three tasks were administered per gesture type and the manual imitation stimuli consisted of meaningless gestures and the actions with objects were also meaningless and could therefore be considered as unconventional actions with objects. In this study, Stone et al.'s (1997) findings

of correlations between object imitation and play were not replicated in the autism spectrum disorder (ASD) group although the correlations were significant for the TD group. Finally, possible motor and social contributions to imitation ability were investigated. A strong association was found between imitation, joint attention, and the Autism Diagnostic Observation Schedule (ADOS) severity.

Although a possible underlying dyspraxia was considered in this study, the 7 items testing praxis consisted of actions with objects (e.g., place a dangling necklace in a tall cup) and were not designed to be imitative but the “affordances of the objects themselves directed the children to perform the tasks” (Rogers, et al., 2003, p. 768). Therefore, this praxis battery differed significantly from traditional tests of praxis used in dyspraxia studies in developmental and adult apraxia experimental designs (Mostofsky et al., 2006; Smith & Bryson, 2007). The authors reported that the battery may not actually reflect a “valid measurement of this construct” (p. 776). Motor planning and motor coordination findings revealed that there was not an autism specific deficit but that fine and gross motor scores were associated with imitation abilities in all three of the groups. The authors encouraged future study into the various underlying mechanisms of imitation in autism.

3.11.2 Dyspraxia ‘Clues’ from Meaningless and Meaningful Gestures

The next two studies tested both meaningful and meaningless gestures, but only in imitation modality. Roeyers, Van Oost, and Bothuyne (1998) tested 18 young children with autism and compared them to 18 subjects with ‘mental retardation’ matching them according to chronological and mental age. The authors tested gestural imitation following Charman & Baron-Cohen’s study (and they, in turn, based their gestural imitation task on the Uzgiris and Hunt, 1975 Scales. The authors tested a familiar visible gesture (e.g., clapping hands); an unfamiliar visible gesture; a familiar invisible gesture; and an unfamiliar invisible gesture. The procedural imitation task followed Meltzoff’s descriptions (1985, 1988).

Results indicated that the autistic children performed differently on all tasks, including gestural imitation, procedural imitation, and joint attention compared to the control group. However, the performance differences were most striking for gestural imitation (half of the autistic group were 'unreliable' imitators). Interestingly, the two unfamiliar gestures, especially the invisible gesture, appeared to be more difficult than the familiar action schemes; in line with later findings about meaningless gesture imitation in autism (Smith & Bryson, 1998; Williams, Whiten, & Singh, 2004). The authors stated that systematic studies of imitation in autism are urgently needed.

In 2007, Vanvuchelen, Roeyers, & DeWeerdts published findings of an experimental design testing motor imitation in 55 school-aged males. They evaluated 8 low-functioning individuals and compared their performance to 13 low-functioning children with learning disabilities and 17 high-functioning individuals with autism and compared them to 17 typically developing children. Following adult neuropsychological studies of apraxia, the authors used a praxis scoring system measuring four different error types: Content (other content and behavioural); spatial (errors of partial imitation, amplitude, body-part-as-an-object, configuration, direction, unrecognizable); temporal (errors of timing, occurrence, sequence, deletions, additions, and transpositions); and behavioural (no response, use of a real object). The authors made three predictions: 1) both autism groups would perform the same types of errors (congruent errors), 2) analysis of the error types would shed light on the underlying cognitive mechanisms of motor imitation, specifically of action-production and action-perception, 3) determine if imitation in ASD is delayed or deviant.

All participants were assessed for motor ability using appropriate standardised evaluations and were tested on 24 different tasks of motor imitation including both meaningful and meaningless gestures. Six transitive gestures, six intransitive gestures, and six meaningless gestures were elicited as well as six meaningless gesture sequences. The authors designed a thorough scoring system subdividing 21 possible error types into 6 categories adding smoothness and compensation to

the categories. Results of the single gestures indicated that the lower-functioning individuals with autism needed more attempts and made more spatial errors including body-part-as-object errors than the control group. The high-functioning group needed more attempts and had amplitude errors.

Importantly, the findings could not be attributed to motor deficits alone and both autism groups performed similar error patterns, confirming the authors' first hypothesis. Spatial errors separated the individuals with autism from the comparison groups, and the authors assimilated the praxis error types into adult neuropsychological theoretical models of apraxia (Rothi et al., 1991).

Vanvuchelen and colleagues (2007) suggested that spatial errors were consistent with a deficit of the action production system, following the findings of Jones and Prior (1985). Further, they argued that the presence of body-part-as-object errors was indicative of a disorder of production, and not a conceptual problem. Citing studies of body-part-as-object errors in younger children, and the presence of mirror image imitation in older individuals with autism typically seen in younger children, the authors suggested that the ASD group showed a delay, and not a deviance, in imitation performance.

3.11.3 Dyspraxia 'Clues' from Pantomimes

Pantomime (the mime of object use), has been used to test adult patients with limb apraxia (Bartolo et al., 2003) as well as children with developmental disorders. Pantomimes are of special interest to developmental researchers due to the symbolic nature of the task. Curcio and Pirscheria (1978) published one of the first papers detailing the performance of pantomimes in a group of 'psychotic' children. Eighteen males and six females ranging in age from 5 to 15 years took part in the study, and all the children were enrolled in a private school for severely disturbed children. The authors reviewed the developmental literature and reported that typically developing children produce pantomimes around 3 years of age, but not until approximately 6 years of age do children represent the objects

without using body-part-as-object errors (BPO) errors. The authors made the comparison to adults with limb apraxia, many of whom also show body-part-as-object errors in their error patterns (Bartolo et al., 2003). The results were summarised as, “very few complete failures” in pantomime. However, this is misleading because the authors report in the results section that in the pantomime to verbal command task, only 23% of the responses were abstract (without BPO errors) and 68% of the children’s responses included BPO productions. In the modelled condition, 38% of the responses were abstract and 54% of the responses included BPO productions. The authors considered a BPO production to be a more primitive response, but they gave credit for the production as a symbolic response. If the authors had counted BPOs as errors, the results would have been reported differently and they may not have reported few failures in pantomime production. No difficulties were reported in imitation of nonsymbolic gestures.

In another study of pantomimes, Bartak, Rutter, & Cox (1975), tested 47 boys between the ages of 4 and 9 years of age with IQ scores of 70 and above, and known language comprehension difficulties. Nineteen of the children were classified as autistic according to the guidelines of infantile autism at the time. Twenty-three children were diagnosed with developmental language delays and were described as ‘dysphasic’ and 5 were considered a ‘mixed’ group. This study is one of the earliest to evaluate both comprehension and production of a specific gesture type. The authors tested pantomimes in a hierarchical fashion beginning with concrete (objects) and moving to abstract (words). To measure gesture comprehension in visual modality, the tester pantomimed an object (e.g., throwing a ball) and the child pointed to the correct object or picture to match the action or named the action. For gesture production in visual modality, the child was shown each stimulus and then asked to show how he would use it but the child could not touch the object. To measure gesture production in verbal modality, the child pantomimed the activity upon request (e.g., “show me washing”). The authors reported that the autistic group was less able to perform all parts of the test but the table of results showed statistically significant results for only three tasks: production of gestures to verbal and visual command and naming a gesture in

visual modality. The latter is a comprehension task that is measured through verbal production but with a visual cue. The authors discussed the dissociation of performance of gesture to command and gesture use in 'free situations'. They questioned whether this was due to 'limited' gestural skills or another reason unrelated to ability. "It does seem that in autism the disability extends beyond spoken language into gesture and inner language" (reflected in imaginative play: Bartak, Rutter, & Cox, 1975, p. 137). The authors suggested that an impairment in 'inner language' was evident in imaginative play in their autistic group.

In 1981, Hammes and Langdell, tested imitation in the context of theoretical precursors of the symbolic development. They used videoclips and tested five different levels of imitation. The first level included two real objects (doll giving a drink); the second level used a teapot and imaginary cup; the third level tested two pretend objects (teacup and pot) and was used to mime object use; the fourth and fifth levels used unconventional objects, one for the teacup and one for the pot. The results revealed that the autistic children were able to copy the actions with the doll and copy object use but performed poorly when they were required to pantomime and to pretend to use one of the objects (real teapot and pretend cup). When an unconventional object was provided, the autistic children did not use the item symbolically, but rather used it as it was intended. The authors found that the autistic children did not imitate symbolic gestures such as pretend objects in pantomimes and that the autistic children showed difficulty at the symbolic or representational levels of gesture production. Subsequently, the more symbolic the test, the more difficult it became and the autistic group demonstrated greatest difficulty producing pantomimes. The authors even went so far as to describe the complete "absence of symbolic gestures" in their description of the gesture of autistic children (Hammes & Langdell, 1981, p. 337) and they recommended further study.

In another study including pantomime production in autism, Rogers, Bennetto, McEvoy, and Pennington (1996), tested two groups of participants ranging in age from 11 to 21. The first group consisted of 17 high-functioning autistic

participants, 15 male and 2 female. The second group, the comparison group, was matched to the autistic group by chronological age and verbal intelligence. All of the participants scored above 69 on the intelligence test. The authors evaluated hand and face imitation as well as pantomime production. The hand imitation tasks were broken down into meaningful and meaningless movements as well as single and sequential movements and were based on tasks used in left brain damaged patients by Kimura and Archibald (1974). In this test (to compare to apraxia terminology), the single meaningful movements were actually intransitive gestures presented in verbal modality, and the single meaningless movements were a combination of arm and hand movements. The sequential meaningless movements included a combination of arm and hand movements with spatial components (e.g., “with fingertips and thumb tip held together and placed on the same shoulder, move the hand out forward and horizontally from the shoulder, rotating and opening it widely as it moves and extends”). The meaningful sequences were two step commands presented in verbal modality.

The authors also included a motor control and memory task to determine if short-term memory deficits may have played a role in gesture imitation errors. The motor control task tested whether gesture production improved after errors were corrected verbally and physically. In the recognition memory task, the experimenter made the gesture and then the participant pointed to the best match.

Tests of pantomimes were included because they are considered ‘classic tests’ of praxis (De Renzi & Luchelli, 1988). The pantomime battery included 20 single mimes of familiar objects (e.g., toothbrush); five sequential pantomimes (e.g., a cup and pitcher); ten direct object imitation; and ten spontaneous object use tasks. The pantomimes were elicited in verbal modality after the participant named the object.

Participants did not show any difficulty in the memory control tasks, passing both meaningful and nonmeaningful measures. In the imitation measures, the autism group performed more poorly than the control group in meaningless gesture

imitation, both single and sequential measures, and imitation of the meaningful sequences. The authors suggested that this was evidence against a symbolic deficit, because meaning improved performance of single hand movements in this group. Neither motor problems nor recognition memory could account for the performance of imitation and pantomimes in the autistic group.

In other words, their autistic group showed no difficulty performing transitive gestures; object use on command; or imitation of intransitive gestures (single hand meaningful) but they did demonstrate errors in pantomime production in verbal modality as well as imitation deficits in meaningless gesture imitation (both single and sequential) and imitation errors of two-step commands. The authors discussed the benefit of holding an object in one's and compared this finding to similar reports of 'utilization' behaviour in patients with frontal lobe damage. The authors stated,

A praxis hypothesis is not independent of an executive function hypothesis. Executive function is involved in the execution of volitional movements and persons with frontal lobe damage demonstrate apraxia. More research is needed to specify the mechanism underlying the imitation and the pantomime deficit in autism (Rogers et al., 1996, p. 2071).

3.11.4 Dyspraxia 'Clues' from Pantomimes and Intransitive Gestures

Perhaps one of the most compelling arguments for a detailed account of praxis processing in autism stems from the initial results of traditional comprehensive praxis examinations administered to individuals with autism revealing that gesture performance is impaired not only in tasks of imitation, but also on command and during tool use (Dzuik et al., 2007). In this study, 47 high-functioning children basic motor skills along with tasks of praxis processing were evaluated, and the results were compared to a typically developing control group. A revised version

of the Florida Apraxia Test was adapted for children and was composed of gestures to command, gestures to imitation, and gestures to tool use (Rothi, Raymer, Ochipa, Maher, & Greenwald, 2003). Pantomimes and intransitive gestures were tested on command and in imitation modalities. Five types of errors were coded: spatial, temporal, concrete/concretization (perseveration and related/nonrelated), BPO, and other. In addition, each participant was evaluated for subtle neurological signs using the PANESS (Physical and Neurological Assessment of Subtle Signs: Holden, Tarnowski, & Prinz, 1982). The authors controlled for age and IQ and found that motor skills were a significant predictor of praxis performance; however, even after accounting for motor skills, the children with autism still demonstrated impairments in performance. The total praxis score contained errors on all three praxis tasks. The authors reported that the results indicated that the praxis examination performance was worse than what would be predicted by motor coordination or clumsiness alone and revealed that an underlying dyspraxic deficit was evident in individuals with ASD.

In developmental disorders, dyspraxia is not considered as the loss of previously acquired motor skills, but rather as an impairment in the acquisition of these skills. Important connections between frontal and parietal regions, as well as in subcortical regions (i.e., basal ganglia and cerebellum), have been identified in the neural network necessary for motor planning and motor learning. The authors suggest that these neural networks, in addition to being important for motor skills necessary for tool use, may also be important for the development of social and communicative gestures. In summary, the authors posit that dyspraxia may be a core deficit in autism or a future marker for this developmental disorder and they emphasise this relationship reporting the positive correlations between the praxis component and the ADOS scores in the high-functioning individuals with autism that they tested.

Moreover, Mostofsky and colleagues (2006) stressed that the processes underlying the resulting imitation deficits in individuals with autism were unlikely to account for impairments in skilled gesture performance in tasks such as pantomiming to

verbal command.

Children with ASD made more total errors on all three sections of the praxis evaluation and also had fewer total percent correct responses when compared to the control group. Importantly, the same pattern emerged for both ASD and the control group; both groups performed lower in tasks of gesture to command than in the other two sections, but without any statistical difference between tool use and imitation. In the gesture to command task, more spatial errors were observed than in the other two sections, but the ASD performed more errors than the control group. The results follow Rogers et al. (1996) findings of impairments of pantomime in high-functioning adolescents with ASD but differ in their findings of tool use. Mostofsky et al. (2006) suggested that the contrasting findings may have been the result of detailed examination of specific error types revealing ASD-associated impairments in actions with objects.

The authors elucidated their findings that impairment of gesture performance was not only evident during tasks of imitation, but also on verbal command as well as with tool use, suggesting that a more generalised praxis impairment is implicated in ASD. Moreover, the findings suggested that in ASD, the acquisition of skilled movements appeared to be delayed and not deviant, given that the distribution of error types in the control group was similar. Correlations between age and gesture performance were significant for the ASD group in all three gesture types but not in the control group; however, the correlation coefficients were not statistically significant between the ASD and control groups suggesting that the correlations may not be valid. Both groups did show improvements in gesture performance with age and these findings follow Zoia et al. (2002) that DCD children demonstrate increases in performance with age.

Finally, the authors highlighted the dyspraxia model outlined by Roy et al. (1990), positing that developmental dyspraxia may be the result of an impairment in the acquisition of spatial representations of movement and/or the motor sequencing programs necessary for accurate production. Possible frontal/parietal-subcortical

circuits were suggested as possible areas of dysfunction.

Dewey, Cantell, & Crawford (2007) conducted a large study of children across developmental disorders including 49 children with ASD, 46 diagnosed with developmental coordination disorder (DCD), 27 with attention deficit hyperactivity disorder (ADHD), and 38 with both DCD and ADHD and compared them to 78 typically developing children. Motor and gestural performance was assessed in all groups. They tested motor functioning using three different standardised tests and children who scored below cutoff on at least two tests were classified as DCD (developmental coordination disorder). The gesture assessment included 6 transitive (pantomimes) and 6 intransitive gestures performed in two modalities, verbal command and imitation. No significant effect sizes for gesture type were identified, so the authors collapsed transitive and intransitive gestures into two groups, gestures to command and gestures to imitation. The results indicated that when covarying for age and IQ, the ASD group performed lower in the motor test than the other groups as well as in their gestural performance of gestures to command and imitation. Final results indicated that the ASD group demonstrated motor impairments (41% of the sample tested); that the children with ASD were the only group that demonstrated gestural performance impairments; and that specific error types were common in the ASD group. Even when controlling for motor skills, the finding of a significant gestural impairment in ASD suggested that motor coordination deficits alone were not the only contributing factor in the observed gestural deficits. The fact that reversal errors were evident in the ASD group provided support for the hypothesis that the neural mechanisms necessary for self-other mapping may be impaired in autism thereby affecting imitation in this developmental disorder. The authors discussed the results in light of additional cognitive hypotheses including mirror neurons, sensory, internal representation, language, and development.

Smith and Bryson (2007) published another important experimental symbolic gesture study as a follow-up to their experiment of nonsymbolic postures (1998),

testing intransitive gestures and pantomimes (referred to as transitive gestures by the authors) in 20 children and adolescents with autism, 20 with language impairment, and 20 typically developing (TD) children. The TD children were matched to the ASD group on measures of receptive language as well as gender. Gesture recognition and gesture production were evaluated. Using a hierarchical approach, the authors tested gesture recognition using 6 trials of pantomimes and 6 trials of intransitive gestures. The examiner produced a pantomime and requested that the participants provide a verbal response to the gesture. Gesture production was evaluated in verbal, visual, and imitation modalities for pantomimes and verbal and imitation modalities for intransitive gestures. Six trials were elicited in each tested modality.

In both recognition tasks, the main effect of group was not significant, although a trend towards significance was identified in the autistic group showing that fewer correct responses were provided when required to spontaneously name demonstrated gestures. In the pantomime production task, results revealed a main effect of group; the individuals with autism were less successful than the other two groups in miming the actions with objects, specially when the pantomimes were elicited in the verbal modality. In intransitive gesture production there was a main effect of group in verbal modality and performance of the ASD group improved when a model was provided. Imitation of intransitive gestures did not reach statistical significance. According to the authors, children in both control groups imitated the actions more accurately than the children in the autistic group.

Interpretation of the findings included discussion of how the results interfaced with the executive functioning hypothesis and in deficits of internal representations. Firstly, the authors stated that not only do children with autism have difficulty imitating meaningless gestures, but the deficit extends to symbolic gestures, in line with recent findings in autism research (Dewey et al., 2007; Mostofsky et al., 2006). After comparing the results of the meaningless gestures experiment to their current meaningful gestures study, the authors reported findings of a greater impairment in symbolic over nonsymbolic imitation.

Eliciting gestures in verbal modality appeared to be more difficult for the individuals with autism than the other groups, and they performed better when a model was provided. Most importantly, the association between gesture recognition and gesture production for intransitive gestures and pantomimes was significantly positively correlated in the two comparison groups whilst the individuals with autism only showed a positive association with communicative gestures.

The authors argue that the ability of the ASD group to recognise gestures that they could not produce goes against a simple representational account of imitation deficits in autism, but that the complexity of gesture processing may require different types of processing for different gesture types following adult models of praxis processing (Cubelli et al., 2000; Rothi et al., 1991). They highlight the findings that gesture recognition and production were not associated in the autism group and cite research in adult apraxia studies stating that recognition and production of gestures is dissociable in adult patient populations (Rumiati, Zanini, Vorano, & Shallice, 2001) but that it is correlated (Buxbaum et al., 2005). However, not all adult apraxia findings follow Buxbaum et al. (2005)'s findings of positive associations (Bartolo et al., 2001; 2003; 2008: See Chapter 3 for a detailed description of praxis processing models). Nonetheless, the authors suggest that the findings of a lack of correlation in the ASD group are important and that gesture studies in development and developmental psychopathology are useful in providing positive contributions to the field of apraxia. Moreover, the modality-specific deficit of gesture to verbal request may be indicative of an inability to access semantic representations in meaningful gesture production. Finally, the authors argue that praxis processing in ASD may reflect the impairments of different sources of cognitive systems, including attention-shifting or the ability to flexibly represent objects. For example, individuals with autism do not use objects creatively in symbolic play and often cannot imitate unconventional use of objects. This may be the result of an inability to inhibit the specific action of the object. They stress the need for a rapprochement between the fields of "cognitive-developmental and developmental-neuropsychological

findings, methods, and models” (Smith & Bryson, 2007, p. 18).

In two studies by Zoia and colleagues (2002, 2004), the development of cognitive functions were evaluated, including motor functioning and the effect of input modalities (i.e., different types of stored knowledge). In their 2002 study, they not only investigated the input modality, but also investigated if the developmental patterns differed in children with developmental coordination disorder (DCD). Gesture in development was studied in 140 children including 35 with DCD divided into three different age groups. Transitive gestures were evaluated across different modalities including verbal (e.g., “show me what you need to do to brush your teeth”); visual (object held up for the participant to view); visual plus tactile (e.g., real object use), and imitation. The results indicated that in every input modality, performance increased with age but that it was less marked as age increased (except in verbal modality). In DCD and the typically developing group, imitation and visual and tactile modalities were performed better and verbal modality scores were the lowest. Not only did the findings confirm a general linear development, but that the specific input modality did affect gestural performance, suggesting that these routes may be achieved at different points of maturation.

In the 2004 study, Zoia and colleagues compared three groups of children: Down’s Syndrome (D), Mental Retardation (MR), and a typically developing group of children (C) matched for mental age. The authors tested different input modalities across three groups of individuals with developmental disorders. Three experiments were conducted. The two groups comprised of children with developmental disabilities performed better in tasks of gesture production than in imitation, especially in tasks of real object use. The authors suggested that this dissociation represented differences in ideational and ideomotor apraxia and most importantly, that the findings strengthened their theory that there are independent processing routes to action. The authors emphasised the need to investigate praxic skills using different input modalities in studies of developmental populations stating that this approach is critical in identifying different routes of processing.

3.12 SUMMARY OF STUDIES

The studies reviewed have included tasks of meaningless gestures, pantomimes to verbal and visual modality, and intransitive gestures. Individuals with ASD were found to be impaired in tasks of meaningless gestures (DeMeyer, 1972; Ohta, 1987); pantomime to verbal modality (Bartak et al., 1975; Dewey et al., 2007; Mostofsky et al., 2006; Rogers et al., 1996); and visual modality (Bartak et al., 1975). However, intransitive gestures (communicative gestures such as wave hand, clap) were evaluated in the context of meaningless or non-symbolic gestures together under the label ‘body movements’ (Stone et al., 1997) and these ‘body movements’ were reported to be more affected than ‘actions with objects’ with individuals with autism (Stone et al., 1997). Others tested intransitive gestures but collapsed them together with pantomimes when analysing the results (Mostofsky et al., 2006; Smith & Bryson, 2007).

CHAPTER 4

METHODOLOGY AND DESIGN OF BATTERY OF TASKS FOR IMITATION AND DYSPRAXIA

4.1 RATIONALE FOR THE ASSESSMENT OF APRAXIA IN AUTISM

In Chapter 3, evidence for fractionation within the imitative system was reviewed, and findings were reported that individuals with autism do not perform all imitative tasks equally (Goldberg, & Denckla, 2006; Hamilton et al., 2007; Mostofsky et al., 2006). As stated by Rogers et al., 2003:

The field has moved beyond asking whether imitation is deficient in autism and is exploring more complex questions involving underlying mechanisms. Are different types of imitation skills relatively independent? What mechanisms lie beneath the imitation difficulty that might help us gain a greater understanding of autism? (p. 766).

Moreover, the presence of gesture production error patterns including spatial temporal, body part as tool, and form errors, has led researchers to suggest that there is reason to believe that dyspraxia in autism is a complex disorder, not limited to imitation deficits (Mostofsky et al., 2006). Williams, Whiten, and Singh, 2004 state that:

Further work is also required to clarify whether certain imitative tasks can better discriminate between autism and dyspraxia, and standardised autism diagnostic processes need to establish how the imitative impairment relates to severity (p. 297).

Consequently, careful consideration of the observable patterns of performance

across different gestural categories is important in the exploration of gestural processing in ASD. Ultimately, it is essential that any research undertaken in dyspraxia in autism be informed by neuropsychological models of praxis processing. A comprehensive assessment of gestural performance in ASD requires the administration of a complete battery of tasks, including detailed scoring methods and procedures similar to those administered to adult patients (Bartolo et al., 2008; Mostofsky et al., 2006; Rothi et al., 1991).

Therefore, only by employing a complete praxis assessment, as done for studying patients with limb apraxia, it is possible to assess dyspraxia in autism participants in a systematic fashion. To date, a model of gestural processing in developmental populations has not been designed. Cermak (1985) reported that traditional tests of apraxia in children had focused solely on meaningless gestures, but that it was important to test both types of gestures; meaningful and meaningless. Moreover, developmental researchers often consider dyspraxia as a unitary disorder and do not take into account the processing across gesture categories and modalities (Cermak, 1985). Efforts to interpret analyses using praxis theories have been constrained secondary to the lack of developmental literature “supporting or extending praxis models” however, existing models are appropriate starting points for organizing and understanding praxis findings in ASD (Smith & Bryson, 2007).

It has been suggested that comprehensive neuropsychological assessments of developmental dyspraxia should include tests of motor, visuomotor, visualperceptual, and language and cognitive skills. “Children’s performance on these measures may also provide suggestions concerning the most appropriate treatment intervention (Dewey, 1995, p. 269). In line with these suggestions and following Bartolo (2002), a battery of tasks was designed for administration that tested each component of the cognitive model. Below, the general design and methods of the experimental tasks that comprise the Apraxia Battery reported in this thesis are described. Further, participant details for both the autism (ASD) and the typically developing control group are provided.

The aims of the imitation experiment were, 1) Determine if an ASD group differs from a group of typically developing controls in their ability to imitate meaningful and/or meaningless gestures, 2) Determine if deficits in gesture imitation are task dependent (transitive, intransitive, pantomimes), 3) Determine if group differences in gesture imitation are better accounted for by underlying cognitive deficits in visual motor (VMI), visual perceptual (VP), and working memory abilities (listening recall, (LR) digit recall (DR) and word list matching (WLM), 4) Identify the specific error patterns of gestural imitation to compare performance of individuals with autism to patients with documented limb apraxia.

4.2 METHODS

4.2.1 Participants

International Review Board (IRB) approval for the research was granted through the Children's Hospital of Wisconsin and the Medical College of Wisconsin (MCW). Ethical approval was also received through the Psychology Department at the University of Edinburgh. All guidelines for the National Institutes of Health (NIH) certification for the testing of human subjects were adhered to and confidentiality agreements and HIPPA regulations were followed according to US federal regulations. After the board approval, all diagnostic, medical, and psychological reports were reviewed.

Nineteen children with ASD, ages 7 to 15 (mean 12.1; SD 2.3), diagnosed with Asperger's Syndrome (16 out of the 19) or High Functioning Autism (3), were recruited through the Autism Society of Southeastern Wisconsin. All children met DSM-IV (APA, 1994) diagnostic criteria for Autistic Disorder or Asperger syndrome, and did not have any other comorbid disorder. Exclusion criteria included: Pervasive Developmental Disorder (PDD-NOS); a Full Scale IQ score below 70; William's Syndrome; anoxia or diffuse cerebral vascular damage and

trauma.

All participants had their diagnosis reconfirmed using the Autism Diagnostic Observation Schedule (ADOS: Lord, Rutter, DiLavore, & Risi, 2002) by examiner H.S.H. who was trained to administer the ADOS for research purposes. All participants were tested using the ADOS Modules 3 or 4 as appropriate (Autism Diagnostic Observation Schedule: Lord et al., 2002), and a parent interview was conducted including the administration of the SCQ (Social Communication Questionnaire: Rutter, Bailey, & Lord, 2003).

The ADOS is a standardised assessment designed to evaluate areas of functioning that are important for the accurate diagnosis of individuals with autism (Lord et al., 2002). The ADOS is described as a semi-structured assessment composed of standard activities and one that “incorporates the use of planned social occasions, referred to as ‘presses’ (Murray, 1938, cit. in Lord et al., 2002), in which a behavior of a particular type is likely to appear” (Lord et al., 2002, p. 1).

The SCQ is a 40-item questionnaire provided to the parents for completion. All questions were presented in a yes/no format and addressed social, communicative, and adaptive behaviour that is not often observed in typically developing children. The items were designed to match items on a more comprehensive parent interview, the Autism Diagnostic Inventory-Revised (ADI-R: Rutter et al., 2003).

Participants were only included in the ASD group if the communication and social interaction total scores exceeded 10 (mean ADOS total for included participants = 17.1, SD = 4.2, range = 12-26). Participants' mean SCQ score was 23.5, SD = 5.7 (range 15-34). These participants were tested either in their homes or in the Division of Neuropsychology, Department of Neurology at the Medical College of Wisconsin.

Twenty-three typically developing children (TD), matched to the ASD group for age (range 7.3-15.8, mean 12.0, SD 2.1), gender, and three tests of intelligence

included in the Wechsler Abbreviated Scales of Intelligence were recruited for this study. Verbal Intelligence (VIQ), Performance Intelligence (PIQ), and Full Scale Intelligence (FSIQ) were all included in the matching assessment. The TD participants were recruited through community resources and tested in their homes. No differences on matching criteria between the 23 TD and 19 ASD participants were found [Verbal Intelligence, Performance Intelligence, Full-Scale Intelligence, and Chronological Age all above significance level using equal variance t-test, $p = ns$]. Table 4.1 provides details of the group characteristics.

Table 4.1
Measures Used in Group Matching

Participants		Age	Gender	IQ		
				Verbal	Performance	Full Scale
TD (N=23)	Range	7.3 – 15.8	21 M/2 F	87 – 134	69 – 143	70 – 139
	Mean	12.0		107.5	112.8	111.4
	(SD)	(2.1)		(12.9)	(18.8)	(16.5)
ASD (N=19)	Range	7.58 – 15	17 M/2 F	81 – 144	72 – 155	79 – 153
	Mean	12.1		106.0	102.5	106.0
	(SD)	(2.4)		(19.0)	(22.7)	(21.0)

Note. TD = Typically Developing Group; ASD = Autism Spectrum Disorder

4.2.2 Preassessment Measures

All participants underwent a general neuropsychological assessment. The standardised tests administered included The Beery Visual Motor Integration Test (VMI), the Beery Visual Perceptual Subtest (VP: Beery & Beery, 2004), and three measures from the Working Memory Test Battery for Children (Pickering & Gathercole, 2001: digit recall, word list matching, and listening recall). All of the standardised assessments are based on a mean of 100 and a standard deviation of 15. A standard score was not calculated for the Beery test of visual perception because the test was not timed; therefore the raw score was tallied for a maximum score of 30 points.

The Beery Test of Visual Motor Integration is a paper and pencil test designed to test the coordination of visual and motor abilities or eye-hand coordination. The test requires the participant to copy geometric shapes of increasing complexity based on a developmental hierarchical approach (Beery & Beery, 2004). See Table 4.2 for the range, means, and standard deviations of the preassessment measures of both groups. The range represents the spread of standard scores in both the ASD and TD groups.

Table 4.2
Cognitive Measures Used in Assessment Sessions

Participants		VMI	VP	Working Memory		
				Digit Recall	Word List Matching	Listening Recall
TD (N=23)	Range	78 – 136	19 – 30	71 – 145	77 – 143	68 – 126
	Mean	102.4	26.5	107.0	106.0	100.3
	(SD)	(13.4)	(2.5)	(21.6)	(16.2)	(16.8)
ASD (N=19)	Range	72 – 109	20 – 30	71 – 141	70 – 120	66 – 109
	Mean	87.6	25.8	98.6	91.8	85.7
	(SD)	(10.4)	(2.6)	(20.2)	(15.1)	(12.9)

Note. TD = Typically Developing Group; ASD = Autism Spectrum Disorder; VMI= Visual Motor Integration; VP=Visual Perception

The Beery Test of Visual Perception requires the participants to match figures of increasing complexity. This test taps into the visual perceptual aspects of the integration of hand and eye coordination tested using the VMI (Beery & Beery, 2004). The range represents the range of the raw score. See Table 4.2 for detailed descriptives.

Three subtests of the Working Memory Test Battery for Children were administered: digit recall, word list matching, and listening recall. The digit recall task required the participant to repeat back a series of verbally presented numbers. As the test progressed, the number of digits to recall increased. The word list matching task required the participant to listen to two series of words

and to report if the word order was the same or different. Again, the number of words required to evaluate increased with each block of trials. Finally, the listening recall task required the participant to not only listen to a series of sentences, but to determine their validity by reporting if the sentence was ‘true or false’. In addition, the participant was required to repeat back the last word of the sentence as the number of sentences to evaluate increased with each series of trials.

Participants did not differ on VP; however, ASD participants performed significantly worse on VMI [$t_{40} = -3.92$, $p < .001$, Cohen’s $d = -1.23$] compared to the typically developing group. For the working memory tests, participants with ASD did not differ from the typically developing control group on the test of digit recall, but they did perform significantly more poorly than the control group on the tests for word list matching and listening recall, [$t_{40} = -2.91$, $p = .006$, Cohen’s $d = -.90$ and $t_{40} = -3.09$, $p = .004$, Cohen’s $d = -.97$ respectively]. Tables 4.1 and 4.2 provide characteristics of the matching and pre-assessment measures for both groups.

Additional standardised measures may have added value to the study including a speech and language assessment and a test measuring motor skills. A language measure, including a test of verbal fluency, could have been included as a predictor of imitation and production performance given that gesture is a form of nonverbal communication and the cognitive model was mapped on a model of language comprehension and production. As described above, the Beery Test of Visual Motor Integration is designed to test the coordination of visual and motor abilities or eye-hand coordination. However, visual motor integration may not predict gesture imitation and production similarly to a task assessing motor skills and motor dexterity such as the grooved pegboard or the finger tapping tests.

4.3 APRAXIA ASSESSMENT

In order to assess apraxia in a population of high-functioning individuals with

high-functioning autism and Asperger Syndrome, a new battery of tasks was developed resulting in the Apraxia Battery for children and adolescents. This new battery was based on tests used in adult apraxia research (Bartolo, 2002; Bartolo et al., 2008; Buxbaum et al., 2005; Goldenberg, 1999) but was substantially altered to make the tasks appropriate and engaging for the target developmental group. In the present battery, age appropriate objects and gestures were presented using videoclips as stimuli and objects were tested both in direct imitation and novel use modalities. The stimuli used in the videoclips included common gestures and household items as well as objects that were familiar to school-aged children and adolescents. The battery was administered using a laptop computer and included the use of still photos and prerecorded videoclips. These were used to ensure consistency of the presented stimuli so that all participants viewed identical executions of each gesture. The stimuli were designed using actors performing gestures and/or using objects. Again, differing from the adult batteries, social scenarios were videotaped in a school setting to test intransitive gestures in the visual modality. These social scenarios were tailored for children and adolescents based on common themes in everyday life (e.g., children running in a hallway). Still photos taken from the social scenarios were then used in the intransitive gesture comprehension task.

In earlier work with adult apraxic patients, coding was performed as the tests progressed. In the present battery, the requirement to keep participants engaged limited the possibilities for immediate coding; hence all participant responses were videotaped and coding was performed subsequent to the administration of the battery. This also allowed for a blind rater to code the gestures to test for interrater reliability. Also differing from adult apraxia batteries, different items were used across gesture categories. This approach was taken to minimise task familiarity because the gestures were tested many times across tasks of recognition, comprehension, and production in verbal, visual, and tactile modalities.

Differing from adult batteries, the participants were not told to begin imitating with either their right or left hand. It appears that there may be differences of opinion where imitating as in a mirror is concerned in developmental contexts. Some authors suggest that mirror imitation is an immature response appearing in children up to the age of six and then decreasing, with children over age ten imitating in a non-mirror fashion (Berges & Lezine, 1965; Smith & Bryson, 1998). Conversely, Avikainen and colleagues (2003) reported that an adult with AS did not imitate in a mirror suggesting that these individuals lacked the “natural preference for imitation in a mirror-image fashion” (Avikainen et al., 2003 p. 339).

All of the actors in the visual stimuli demonstrated the gestures with their right hand. The participants were not instructed with which hand to begin the production or imitation of the gesture. In other words, they could naturally imitate initiating each trial with either their right or left hand. All of the participants were right handed except one individual with Asperger Syndrome. Not only were order effects considered (See Section 5.1.3), but also mirroring effects were considered when comparing the results of the right and left hand performance. In this current study, the participants did not perform better with the ‘mirroring’ hand or conversely with the actual hand depicted in the stimuli.

The newly designed battery of tasks has not been normed and hence the scoring categories reflect only the author’s assessment of a correct or incorrect response. However, in the task of production of intransitive gestures to verbal and visual stimuli, the content of the gesture was considered as correct if two or more typically developing participants produced the same gesture. Moreover, all gestures were coded by a rater blind to the hypothesis of the study.

See Appendices B-G for a detailed description of the stimuli used for each task administered in the Apraxia Battery. Appendix A includes the Apraxia Battery clinical forms; Appendices B, C, and D include the pictorial stimuli administered in Experimental Task 4, 5, and 6 respectively. Appendix E includes the pictorial

stimuli administered in Experimental Tasks 16 and 17; and Appendix F includes the pictorial stimuli administered in Experimental Tasks 18 and 19. See Figure 4.1 for a hierarchical organisation of the gestures tested in the newly designed Apraxia Battery.

The following subtests were administered as part of the Apraxia Battery:

- Two tasks assessing meaningless gestures
- Three tasks assessing recognition of gestures
- Three tasks taxing the comprehension of gestures
- Three tasks for the assessment of the production of gestures
- Three tasks assessing the imitation of meaningful gestures

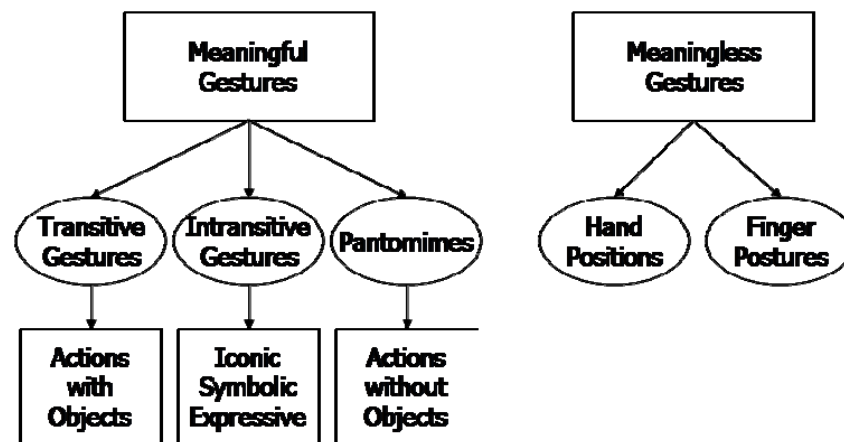


Figure 4.1. Hierarchical organization of meaningful and meaningless gestures tested in the newly designed Apraxia Battery.

4.3.1 Two Tasks Assessing Meaningless Gestures

Imitation of Meaningless Gestures.

Materials

The meaningless gestures imitation task was based on studies of meaningless gestures in adult patient populations (Goldenberg, 1999). Ten still photos of hand postures and ten still photos of finger positions were administered. The photos were real-life colour photographs of child actors demonstrating hand postures and finger positions. The still photos for both

hand postures and finger positions were 14 cm in length and 10.5 cm in height on a solid gray background. See Fig. 4.2 for a stimulus example and Appendix E for the pictorial stimuli.

Procedure

The stimuli were presented via laptop computer. The participants viewed ten hand posture stills and ten finger positions (one at a time), and were asked to imitate. The participants were instructed that they were going to see a series of photographs of people doing different things with their hands. A still photo example was presented on the laptop monitor and the participants were instructed to “*Do what he/she just did.*” The photo was visible on the monitor until the participants imitated the meaningless gesture. Each participant was allowed two attempts to imitate each gesture; one with each hand but they were not instructed as to which hand to use first. All gestures were videotaped, and the recordings were subsequently coded by two raters, one of whom was blind to the experimental hypothesis. The posture achieved at the end of the imitation attempt was coded.

Coding

For a gesture to be considered correct, it had to conform to the following properties: the hand had to be in the same shape as the model (form) as well as in the same position in relation to the various body parts (body part orientation). The orientation had to be in the same plane and the response could not be rotated more than 180 degrees (rotation). All other gestures were coded as “incorrect”.

- *Form error*: One error score was given if the hand posture or the finger position was not in the correct shape or configuration.
- *Body part orientation error*: One error score was given if the hand was not in the correct position in relation to the other parts of the body even if the configuration was accurate.

- *Rotational error*: One error code was given if there was a 180 degree rotation in the hand posture or finger position.



Figure 4.2. Sample material taken from the Imitation of Meaningless Gesture stimulus set (target hand posture). Participants were asked to copy the action that they viewed on the screen.

Matching of Meaningless Gestures

Materials

The same real-life colour photographs of actors demonstrating hand postures and finger positions that were used in the imitation task were also used in the matching task. Following Goldenberg (1999), photos of different people taken from different angles of view were used in the four still photos. The position of the correct match was randomised on the screen. Each photo was 4 cm x 5 cm. The photos on the right consisted of one matching gesture and three foils. See Fig. 4.3 for a stimulus example and Appendix F for the pictorial stimuli.

Procedure

In the matching tasks, participants viewed stills of hand postures and finger positions on a laptop computer screen. In each trial, the participants

were shown one target photo (either hand posture or finger position) on the left of the screen, and four choices were provided on the right side of the screen.

The participants sat at a table across from the laptop computer so they could easily see the computer screen. Participants viewed ten hand and ten finger targets, and were asked to choose the photo among a set of four pictures that was the best match to a target one.

Coding

Each correct match resulted in a correct trial, resulting in a maximum of ten correct matches for each trial of finger and hand matching.



Figure 4.3. Sample material taken from the Matching of Meaningless Gesture stimulus set. Participants were asked to indicate which of the right-hand photos showed the same posture as the photo on the left.

4.3.2 Three Tasks Assessing Recognition of Meaningful Gestures

Recognition of Pantomimes.

Materials

The pantomime recognition task included 10 videoclips of actors performing 'real' pantomimes and 10 videoclips of actors performing

‘invented’ pantomimes. The invented pantomimes were made up of familiar pantomimes containing errors (i.e., writing with a pen upside down). See Fig. 4.4 for an example of an invented pantomime and Appendix A for the stimuli listed in the clinical forms.

Procedure

In the pantomime recognition task, the participants were asked to state if the person in the videoclip was pretending to use the object correctly or incorrectly. They were instructed, “*In each video, you will see a person pretending to use an object.*” Then the participants were shown an example videoclip and instructed, “*Please say yes if they are pretending to use the object correctly or no if they are not*”. See Fig. 4.5 for an example of a correct pantomime production and Appendix A for the stimuli listed in the clinical forms.

Coding

Each correct recognition resulted in a correct trial, resulting in a maximum of twenty correct trials.



Figure 4.4. Sample material of a False Pantomime Production (typing with the keyboard upside-down) taken from the Recognition of Pantomimes task included in the Meaningful Gestures stimulus set. Participants were asked to indicate if this was a correct or an incorrect production.



Figure 4.5. Sample material of a Real Pantomime Production (putting on headphones) taken from the Recognition of Pantomimes task included in the Meaningful Gestures stimulus set. Participants were asked to indicate if this was a correct or an incorrect production.

Recognition of Transitive Gestures

Materials

The transitive gesture recognition task included 10 videoclips of actors correctly using common objects and 10 videoclips of actors performing incorrect object use with common objects. All videoclips were edited to a 5-second duration. See Figs. 4.6 and 4.7 for stimuli description and Appendix A for the stimuli listed in the clinical forms.

Procedure

Twenty trials testing the recognition of transitive gestures were administered. The participants were instructed, *“In each video, you will see a person using an object. Please tell me if they are using the object correctly.”* The participants were shown an example videoclip and instructed, *“Please say yes if the person is using the object correctly and no if they are not.”*

Coding

Each correct recognition resulted in a correct trial, resulting in a maximum of twenty correct trials.



Figure 4.6. Sample material of Incorrect Object Use (using a toothbrush as a screwdriver) taken from the Recognition of Transitive Gestures task included in the Meaningful Gestures stimulus set. Participants were asked to indicate if this was a correct or an incorrect production.



Figure 4.7. Sample material of Correct Object Use (putting on headphones) taken from the Recognition of Transitive Gestures task included in the Meaningful Gestures stimulus set. Participants were asked to indicate if this was a correct or an incorrect production.

Recognition of Intransitive Gestures

Materials

The intransitive gesture recognition task included ten videoclips of actors performing communicative gestures correctly and ten examples of actors performing meaningless gestures. The meaningless gestures were invented and were not real. See Figs. 4.8 and 4.9 for examples of trials assessing the recognition of intransitive gestures using familiar and unfamiliar gestures and Appendix A for the stimuli listed in the clinical forms.

Procedure

The participants were asked to determine if the gesture in the videoclip was familiar or not. They were instructed, *“In each video, you will see a person making a gesture. Please tell me if you have seen it before.”* Then the participants were shown an example videoclip and instructed, *“Please say yes if you have seen the gesture before and no if you have not.”*

Coding

Each correct recognition resulted in a correct trial, resulting in a maximum of twenty correct trials.



Figure 4.8. Sample material of an unfamiliar gesture (opening and closing hand) taken from the Recognition of Intransitive Gestures task included in the Meaningful Gestures stimulus set. Participants were asked to indicate if this was familiar or unfamiliar.



Figure 4.9. Sample material of a familiar gesture (peace) taken from the Intransitive Gesture Recognition task included in the Meaningful Gestures stimulus set. Participants were asked to indicate if this was familiar or unfamiliar.

4.3.3. Three Tasks Taxing the Comprehension of Meaningful Gestures

Comprehension of Pantomimes

Materials

Twenty trials evaluating pantomime comprehension were designed. Each trial contained four realistic colour pictures of common objects copied to white 8.5 in x 11 in US standard size paper. The pantomime comprehension trials were comprised of pictures of the correct choice and three foils, or incorrect choices. The three incorrect foils included one picture of a semantically related object, one visually similar picture choice, and one unrelated distractor. Each photo was 9.5 cm x 13.5 cm. See Fig. 4.10 for a stimulus example testing pantomime comprehension. See also Appendix A for the stimuli listed in the clinical forms and Appendix C for the pictorial stimuli.

Procedure

The experimenter provided the following instruction, “*Now I will pretend to use an object. Look at the pictures of the objects and point to the one that you think I am pretending to use*”. The experimenter produced a pantomime and the participant pointed to the picture that best matched the gesture.

Coding

Each correct match resulted in a correct trial, resulting in a maximum of twenty correct trials.



Figure 4.10. Sample material of a pantomime comprehension stimulus (basketball) taken from the Comprehension of Pantomimes task included in the Meaningful Gestures stimulus. Participants were asked to point to the picture of the object that the examiner pretended to use.

Comprehension of Transitive Gestures

Materials

Twenty trials evaluating the comprehension of transitive gestures were designed. Each trial contained three realistic colour pictures of common objects copied to white 8.5 in x 11 in US standard size paper. The trials were composed of one target picture and two choices. Following Bartolo (2002), the choices included one object that was closely related to the target picture and one semantic distractor. Each picture was 9.5 cm x 13.5 cm. See Fig. 4.11 for an example of a trial evaluating transitive gesture comprehension. See also Appendix A for the stimuli listed in the clinical form and Appendix B for the pictorial stimuli.

Procedure

The experimenter provided the instructions for the task, *“Look at all of the pictures. Point to the picture on the bottom that you think best goes with this picture (experimenter pointed to the top picture).”*



Figure 4.11. Sample material of a transitive gesture comprehension stimulus (money) taken from the Comprehension of Transitive Gestures task included in the Meaningful Gestures stimulus. Participants were asked to point to the picture of the object on the bottom that was the most strongly associated with the picture on the top testing their comprehension of common objects.

Coding

Each correct match resulted in a correct trial, resulting in a maximum of twenty correct trials

Comprehension of Intransitive Gestures

Materials

The comprehension of intransitive gestures task was designed using still photos taken from the production of intransitive gestures in visual modality videos. Four still photos appeared on the computer screen. The photos were 8 cm in height and 11 cm in length. One picture was correct and three were incorrect choices. The correct picture position was randomised. See Fig. 4.12 for an example trial of intransitive gesture comprehension. See also Appendix A for the stimuli listed in the clinical forms and Appendix D for the pictorial stimuli.

Procedure

The experimenter provided the following instruction, *“Now I will make some gestures. Look at the pictures and point to the one that you think goes the best with my gesture.”*

Coding

Each correct match resulted in a correct trial, resulting in a maximum of twenty correct trials.



Figure 4.12. Sample material of a comprehension stimulus taken from the intransitive gesture comprehension task (example of smelly, 'peeyu'). Participants were asked to point to the picture that best matched the production of the examiner.

4.3.4 Three Tasks Assessing the Production of Gestures

Production of Transitive Gestures

Materials

This task evaluated object use and included common objects. Spontaneous object use was tested with the following common objects. Twenty trials of production of transitive gestures were planned for administration but two of the items were not available for testing so only 18 trials were administered. See Appendix A for the stimuli listed in the clinical forms.

Procedure

In this task, the participants were given one object at a time and instructed to “*Use this object.*”

Coding

(See end of section)

Production of Intransitive Gestures

Materials

Verbal Modality

In this task, 20 trials of intransitive gesture production in verbal modality were administered. The verbal trials were read aloud to the participants and included short scenarios of common social situations. See Appendix A for the stimuli listed in the clinical forms

Visual Modality

The production of intransitive gestures in visual modality was assessed using videotaped scenarios. The videoclips were 6 to 17 seconds in duration and included scenes from school settings and familiar surroundings such as the library, cafeteria, and gymnasium. See Figs. 4.13-4.15 for an example of the visual stimuli. See also Appendix A in the clinical forms for a list of the social scenarios administered.

Procedure

Verbal Modality

The participants were told, “*I am going to read you some short stories. Listen carefully.*” Then the example verbal scenario was read aloud and the participants were asked, “*What gesture would the _____ make in this situation?*” Each trial was read aloud to the participant a maximum of

two times. For example, in this trial, the participant heard, “A *boy was mowing the lawn in the heat of the summer. Sweat was dripping down his face. As he stopped to take a break, what gesture would he make?*”

Visual Modality

After the participants viewed the example videoclip, they were asked, “What would the _____ (*boy/girl/mother/teacher*) do in this situation?” For example, in one scenario, a boy was performing on a stage. After he finished his performance he gave a bow. The camera then panned to a girl sitting in the audience. The experimenter asked, “What gesture would the girl make in this situation?” See Fig. 4.13 for a photo that was taken from the social scenario videos.

Coding

(See end of section.)



Figure 4.13. Still of a videoclip used in production of intransitive gesture in visual modality (an actor bowing after a performance).

In another videoclip, two boys were sitting at a table in the library. The first boy began to put his books in his backpack and prepared to leave. As he walked away from the table, he turned back to the second boy sitting at the table and paused.

The experimenter then asked, “*What gesture would the boy make in this situation?*” See Figs. 4.14-4.15 for an example of the visual stimuli used in the task. See also Appendix A for the stimuli listed in the clinical forms.

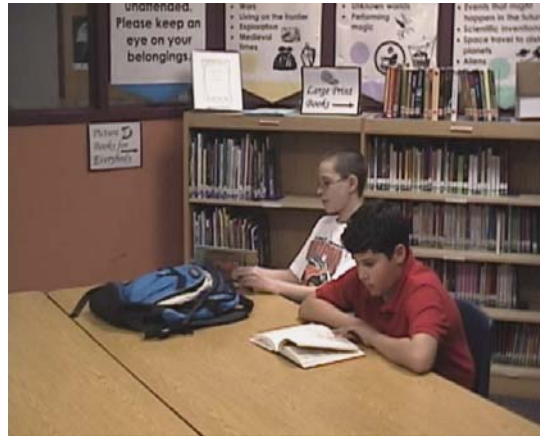


Figure 4.14. Production of intransitive gesture in visual modality (beginning of videoclip).



Figure 4.15. Production of intransitive gesture in visual modality (end of the videoclip the target gesture was to wave goodbye).

Production of Pantomimes

Materials

Verbal Modality

Twenty trials of pantomime production in verbal modality were administered. The objects testing pantomime production included common objects that children often use as well as objects they may see other people using in their household or environments. The objects included: zipper (example), ball, bell, Gameboy, paper airplane, razor, soap, sponge, book, stapler, harmonica, paintbrush, drumstick, wagon, broom, marker, eraser, pencil, drawer, piano, light switch.

Visual Modality

Twenty trials of pantomime production in verbal modality were administered. Following pantomime production in verbal modality, the objects used to elicit pantomime production in visual modality were administered and included common objects that children often use and objects they may see other people using in everyday situations. The objects included: baseball hat (example), paper airplane, spoon, remote control, key, yo-yo, banana, screwdriver, hammer bubble wand, toothbrush, camera, Gameboy, drumstick, hole punch, ball, salt shaker, recorder, ring, hairbrush, backpack.

Tactile Modality

Twenty trials of pantomime production in tactile modality were administered. The stimuli for the task included: racket (example), toothbrush, eyeglasses, pen, book, butter knife, hairbrush, cup, hat, remote control, ball, yo-yo, spoon, child-safety scissors, Chapstick, wooden spoon, rope, shovel, bubble wand, Play-Doh, stuffed toy.

Procedure

Verbal Modality

The participants were told, “*Show me how you would use a toothbrush.*”

Visual Modality

In this task, the objects were held in view for the participants to see and they were instructed, “*Show me how you would use this object.*” The object was visible until the participants began the pantomime production. The participants were not allowed to use or hold the object during this task.

Tactile Modality

In this task, participants were instructed that they were going to play a guessing game and they were asked to close their eyes. They were told, “*I am going to put something in your hands after you close your eyes. I want you to feel it and show me how you would use this object.*”

Coding

(See end of section.)

4.3.5 Three Tasks Assessing the Imitation of Meaningful Gestures

Imitation of Transitive Gestures

Materials

The materials used in the transitive gesture imitation task included 20 videoclips of actors using common objects and household items including a hairbrush (example), locker combination lock, computer mouse, bell, nailbrush, rolling pin, tape measure, calculator, instrument (recorder), hole punch, guitar pick, bottle, spatula, binocular, camera, remote control, ball,

paper airplane, spoon, keyboard and baseball cap. See Fig. 4.16 for a sample photo taken from a videoclip testing imitation of transitive gestures. See Appendix A for the stimuli listed in the clinical forms.

Procedure

After the participants were told that they would watch a series of videoclips of people using objects, they viewed the example videoclip. Next, the experimenter said, “*Do what he/she just did.*” Then, the appropriate object was handed to the participant and they used the object as demonstrated. The examiner asked for the return of the object and the next videoclip was played. The participant viewed and imitated 20 trials of imitation of transitive gestures.

Coding.

(See end of the section.)



Figure 4.16. Sample material of an imitation stimulus taken from the transitive gesture imitation task (putting on a hat). Participants were asked to imitate the action of the actor on the videoclip.

Imitation of Intransitive Gestures

Materials

The materials used in the intransitive gesture imitation task included 20 videoclips of actors performing common communicative gestures including a peace sign (example), money; all done; too loud; look; listen; read; swatting a fly; crazy; stop; pay; choke; don't look; blow a kiss; throw a punch; let's go; roll the dice; hands up; you; cold; hot. See Fig. 4.17 for an example of intransitive gesture imitation and Appendix A for the stimuli listed in the clinical forms.

Procedure

The participants viewed and imitated 20 videoclips of actors performing intransitive gestures. The procedures followed the general procedures as well as the previously described procedure for the imitation of transitive gestures task except that the participants were not provided with objects to use in their imitative trial.



Figure 4.17. Sample material of an imitation stimulus taken from the Intransitive gesture imitation task (example of money). Participants were asked to imitate the action produced by the actor in the videoclip.

Imitation of Pantomimes.

Materials

The materials used in the pantomime imitation task included 20 videoclips of actors pretending to use objects; the mime of object use, including as camera (example), knife, wooden spoon, salt shaker, toothbrush, paper, rain hood, pitcher, bow and arrow, shovel, rope, peeler, weight, hat, key, headphones, book, snowball, yo-yo, cup, key, and soap. See Fig. 4.18 for an imitation stimulus taken from the pantomime imitation task and Appendix A for the stimuli listed in the clinical forms.

Procedure

The participants viewed and imitated 20 videoclips of actors performing pantomimes. General procedures were followed as well as the procedures for the imitation of transitive gestures task except that the participants were told that they would view videoclips of people pretending to use objects.



Figure 4.18. Sample material of an imitation stimulus taken from the Pantomime imitation task (example of taking a picture). Participants were asked to imitate the action produced by the actor in the videoclip.

Coding

The coding system for all of the imitation tasks was designed with a coding specialist (Jean Carletta) using a system designed to measure behaviours typically associated with autism, as well as errors observed in praxis processing used in neuropsychological studies of limb apraxia (Bartolo, 2002; Buxbaum et al., 2005). All three tasks (imitation of transitive gestures, intransitive gestures, and pantomimes) included four codes that were consistent throughout all three imitation tasks and were used in analysis: hand; arm trajectory; amplitude, and timing. For each correct performance, participants received a score of 1.

Participants who did not commit any errors received a maximum score of 20 out of 20 trials. The coding system was designed to measure the number and types of errors present during the production. For example, if a participant demonstrated a hand posture error, they did not receive credit for a correct response for that trial and received an error tally for hand posture.

- *Hand posture error*: A score of 1 was given if an error of the hand was observed. For example, if the hand configuration was not accurate or the hand posture was non-specific or the wrist angle was incorrect. This code also encompassed hand grip; for example, if the object was held incorrectly.
- *Arm posture/trajectory error*: A score of 1 was given if there was an error related to the arm. For example, the arm was not in the right shape for the movement (e.g. circular instead of linear), or the arm was at the wrong angle, or in the incorrect plane (e.g. side to side instead of back and forth).
- *Amplitude error*: A score of 1 was given if there was an error related to the size of the movement. For example, a movement was either too big or too small. (e.g., overshooting or undershooting a target).
- *Timing error*: A score of 1 was given if there was an error related to the speed of movement; for example, the speed was not correct or the

number of cycles was not enough or too many (i.e., hammering only one time in a pantomime).

Codes specific to particular gesture types:

- *Other gesture*: A score of 1 was given if the participant either produced or imitated a different gesture than the one demonstrated or imitated the pantomime of an object other than the one demonstrated.
- *Reversal Error*: A score of 1 was given if the participant imitated the gesture by taking the perspective of the demonstrator (For example, imitating the intransitive gesture of 'crazy' in the opposite direction).
- *Body-Part-as-Object error*: A score of 1 was given if the participant used a body part for the intended action (i.e., using their finger as a pen).
- *Distance error*: A score of 1 was given if the participant performed the gesture at the incorrect distance from the target (e.g. shaking salt from a shaker at the level of the shoulder).
- *Don't know*: A score of 1 was given if the participant verbalised, "I don't know" in response to presented stimuli.

Each gesture was recorded and subsequently coded by two raters, one of whom was blind to the experimental hypothesis. Seven examples of each error type were coded for inter-rater reliability resulting in an 80% agreement in the meaningless gesture imitation task (rising to 100% when disagreements were discussed); 86% agreement in the imitation of meaningful gestures task (again, rising to 100% when disagreements were discussed); and 82% agreement in the meaningful gesture production task (agreement reached following discussion).

CHAPTER 5

IMITATION OF MEANINGLESS AND MEANINGFUL GESTURES

5.1 MEANINGLESS GESTURE IMITATION¹

5.1.1 Introduction

Imitation is an early and important developmental milestone that continues throughout the lifespan (Metzloff & Moore, 1977, 1983). Infants imitate adult models (Metzloff & Moore, 1977). Children imitate one another during social games and peer interactions (Nadel, 2006). Adults imitate during communication exchanges (Chartrand & Bargh, 1999). A link between a perceived and performed action appears to be hardwired in humans. Metzloff and Decety (2003) suggest that motor imitation is the ‘missing link’ between perception action coding and the development in the foundation of ‘self and other’. Recent imitation research is now merging the study of the neural basis of human imitation with the models of common coding (Chaminade, Meltzoff & Decety, 2005). Elicited imitation comes under the umbrella of interpersonal matching, and has been defined (e.g., by Moody & McIntosh, 2006) as the copying of the action of a model rather than matching the outcome of the action by different means (cp. emulation).

In parallel, several prominent imitation models provide theoretical explanations to account for the differences in the various types of imitation and their underlying neural correlates (Heyes, 2001; Bekkering, Wohlschlager, & Gattis, 2000) and theories examining the relationship between imitation and autism are being explored (Rogers & Pennington, 1991; Williams et al., 2001). Rogers and Pennington (1991) suggested that a primary deficit in imitation may create a

¹ A version of the hand and finger imitation experiment has been published in the *Journal of Autism and Developmental Disorders*. The published article can be found in Appendix G.

cascading effect in the lack of development of symbolic thinking, emotion-sharing, joint attention, and theory of mind. The mirror neuron system theory (MNS) extended Rogers and Pennington's imitation theory (1991) and suggested that the faulty development of the mirror system in individuals with ASD may be responsible for the noted deficits in self-other mapping and the social cognitive deficits so prevalent in this population (Williams et al., 2001).

However, as new imitation research is published in the autism literature, the question remains as to the specific nature of the underlying imitation deficit; for example, whether or not all individuals with autism demonstrate imitation impairments, if all types of imitation tasks are performed similarly, and if there is a difference between imitating meaningful (e.g., symbolic) versus meaningless (e.g., non-symbolic) gestures. Further, imitation can be subdivided into the imitation of meaningful and meaningless gestures, which can be considered separately

Studies in adults with limb apraxia often include the assessment of both meaningful and meaningless gesture imitation (Bartolo et al., 2008; Cubelli, et al., 2000). Meaningless gestures are a unique gesture category and are often tested separately from other gestures, both in clinical settings and for research purposes (Bartolo et al., 2001; Cubelli, Bartolo, Nichelli, & Della Sala, 2006; Tessari et al., 2007). An additional advantage of the differentiation of meaningful and meaningless gesture production in testing individuals with autism is that the production of meaningless gestures *requires* direct matching from one person to another. In contrast to the production of meaningful gestures, the imitation of meaningless gestures cannot rely on prior knowledge or gesture meaning (Goldenberg & Karnath, 2006), and their performance cannot be improved by object affordances. In fact, novel gestures have been proposed to be the most genuine test of imitation because representations cannot be elicited from long-term memory (Goldenberg & Hagmann, 1997). It has also been suggested that meaningless gestures are the most useful test in diagnosing ideomotor apraxia (De Renzi & Faglioni, 1999).

Additionally, meaningless gesture imitation has been reported to dissociate from meaningful gestures in adult patient populations (Bartolo et al., 2001; Cubelli et al., 2000). A patient's ability to produce meaningless gestures may be impaired whilst the production of meaningful gestures remains unaffected (Goldenberg & Hagmann, 1997); the opposite pattern has now been reported for the first time (Bartolo et.al, 2001). Here, an exploratory study based on tests of the imitation of meaningless gestures adapted from Goldenberg (1999) is discussed.

In studies of brain-damaged patients Goldenberg (1999; Goldenberg & Strauss, 2002) reported that brain damaged patients with lesions in the left inferior parietal lobe demonstrated deficits in imitation of hand postures whilst patients with damage to the right inferior parietal lobe demonstrated impairments of the imitation of finger positions (cp. Della Sala, Faglioni, Motto, & Spinnler, 2006). Goldenberg suggested that hand and finger imitation may tap into different systems: Imitation impairments of the hand may result from deficits in body part coding and 'conceptual mediation' and imitation impairments of finger positions may result from deficits in visuospatial analysis (Goldenberg, 1999, Goldenberg & Strauss, 2002). Goldenberg suggested that imitation requires mapping from one person to another even from different angles and spatial positions, taking into consideration the differences in the physical attributes of the body including size, height, and shape (Goldenberg & Hermsdorfer, 2002). Body part coding, according to Goldenberg (1999) involves translating the features and the 'concept' of the human body including the boundaries that define it (Goldenberg & Hagmann, 1997).

Although autism is a developmental, and not an acquired disorder, neurological dysfunction in various brain regions has been implicated in both the right and left hemispheres in individuals with autism (Castelli, Frith, C., Happe, & Frith, U., 2002). To date, studies have not been designed to evaluate hand and finger imitation in individuals with ASD. Although studies have been conducted testing non-symbolic or meaningless gestures, the gestures have often been combined into one movement, incorporating the hand and fingers together in one gesture

(Smith & Bryson, 1998). To date, studies have not evaluated hand and finger gestures separately in ASD, although they have been reported to dissociate in neurological patient populations (Goldenberg, 1999, Goldenberg & Hagmann, 1997; Goldenberg & Strauss, 2002). Observing how ASD participants perform on the two different tasks may provide insight into the specific basis of their imitation deficits. It is important to distinguish that the patients that Goldenberg studied were adults with acquired brain lesions, while the current study evaluated participants with high-functioning autism and Asperger Syndrome which are neurodevelopmental disorders.

The research questions for the imitation of meaningless gestures were as follows:

1) To determine if autistic children demonstrate impairments in imitation of meaningful gestures compared with typically developing children, 2) To assess the performance of hand and finger imitation across tasks to explore the nature of task dependency in ASD, 3) To identify the underlying cognitive mechanisms that may have an influence on imitative performance, and 4) To investigate whether hand and finger imitation tasks are failed for different reasons.

5.1.2. Method Review

Meaningless gesture imitation and matching tasks were administered to two groups, one group comprised of individuals with ASD and the other, a control group composed of typically developing peers (see Method section in Chapter 4 for a detailed description). The two groups were carefully matched (see Table 5.1 for group matching characteristics). The Wechsler Abbreviated Scales of Intelligence (WASI) was administered to assess Verbal Intelligence (VIQ), Performance Intelligence (PIQ), and Full Scale Intelligence (FSIQ). Additional standardised cognitive tests were also administered including the Beery Test of Visual Motor Integration (VMI), the Beery Test of Visual Perception (VP) and three subtests of the Working Memory Test Battery for Children including Digit Recall (DR), Word List Matching (WLM), and Listening Recall (LR) but were

not used in the group matching. See Table 5.1 for group characteristics on the preassessment measures. All of the standardised assessments are based on a mean of 100 and a standard deviation of 15. A standard score was not calculated for the Beery test of visual perception because the test was not timed, so the raw score was tallied for a maximum score of 30 points.

The meaningless gestures tasks were based on tests of recognition and imitation used in adult neuropsychological studies and these current tasks were adapted from Goldenberg's research on visuoimitative apraxia (Goldenberg, 1999). Two meaningless gesture imitation experimental tasks were included: *Matching* of hand postures and finger positions and *Imitation* of hand postures and finger positions (see Appendix A for the description of the stimuli). In the matching task, ten static stimuli for each type of task were presented via laptop computer. The participants sat across from the computer while they viewed ten targets for hand matching and ten targets for finger matching. Each gesture type was tested in blocks: ten photos of hand postures to match and ten photos of finger positions. For each trial, the participants were shown one target still photo (either a hand posture or a finger position) visible on the left side of the computer screen, together with a match to the target still photo with three additional foils on the right. Consistent with Goldenberg (1999), each trial comprised photos of different people photographed from various angles. Participants viewed ten hand and ten finger targets, and were instructed to choose the matching still photo on each trial. For each correct performance, participants received a score of 1, thus participants who did not commit any errors received a maximum score of 10 out of 10 trials per gesture type.

For the imitation task, ten static stimuli for each type of meaningless gesture task were presented via laptop computer. The participants sat across from the computer while they viewed ten targets of hand postures and ten targets of finger positions. The participants were instructed to imitate the gesture after viewing each still photo. A coding system was designed to measure the number and types of errors present during the production. For example, if a participant demonstrated a hand orientation error, they did not receive credit for a correct

response for that trial, in addition to receiving an error tally for the particular error type. The codes were a combination of error codes used in adult apraxia studies (Bartolo et al., 2008; Buxbaum et al., 2005; Goldenberg, 1999) and autism research (Rogers et al., 1996). The participants were videotaped while they produced the gestures, for coding purposes. Each gesture was recorded and subsequently coded by two raters, one of whom was blind to the experimental hypothesis and the other was one of the authors (H.S.H.). For each correct performance, participants received a score of 1, thus participants who did not commit any errors received a maximum score of 10 out of 10 trials per hand posture and finger position imitation.

5.1.3 Results of Meaningless Gestures

Approach to Analysis

The meaningless gesture data analyses were performed in five consecutive steps: 1) evaluating group differences in task performance between the individuals with autism and the typically developing controls, 2) comparing task performance across gesture types in both groups, 3) predicting underlying cognitive mechanisms necessary for successful imitation, 4) assessing error types and 5) exploring correlations and relationships between cognitive variables and imitation tasks.

Hand Choice

The participants were not instructed with which hand to begin imitating. In other words, they could naturally imitate initiating each trial with either their right or left hand. Therefore, the right and left hands may have comprised the first or second imitation attempt. To determine if the participants improved in the second attempt, the first and the second imitations were compared using paired sample t-tests. A paired sample t-test was performed to determine if any differences in the

two attempts could be attributed to practice effects. Results of the t-test did not reveal any differences between the first and second attempts for either hand [ASD $t_{18} = .000$, $p = 1.00$; TD $t_{22} = .81$, $p = .43$] or finger imitation [ASD $t_{18} = -.77$, $p = .46$; TD $t_{22} = .57$, $p = .58$] in either the ASD or TD group, so the subsequent analyses were collapsed.

Group Differences

Welch's independent t-tests were used to determine group differences in the performance of hand and finger tasks. Welch's t-tests were selected over Mann-Whitney U tests as the analysis of choice to account for the unequal variances in the tested samples. Significant between-group differences were revealed, with the autism participants performing both tasks of *imitation* more poorly than the TD group [hand imitation $t_{22} = -3.58$, $p = .002$ Cohen's $d = -1.12$; finger imitation $t_{25.5} = -2.95$, $p = .007$, Cohen's $d = -.89$]. See Table 5.1 for the descriptive statistics.

Table 5.1
Descriptive Statistics for Hand and Finger Imitation

	ASD	TD	Test
	N = 19	N = 23	Statistic
Hand Imitation	6.79 ± 2.50	8.96 ± 0.92	$t_{22} = -3.58$, $p = .002$
Finger Imitation	7.45 ± 2.05	8.98 ± 1.04	$t_{25.5} = -2.95$, $p = .007$

Note. Mean ± SD. Test used: Welch's t test.

Predicting Group

The first analysis was conducted to establish which variables best accounted for group differences; all six variables described above (Visual Motor Integration; Visual Perception; hand and finger matching, hand and finger imitation) were entered into a stepwise logistic regression predicting group membership. This

yielded a 2-factor model which improved prediction by 26.2%, to 81.0% correct, over the null model. Other than VMI, which improved prediction by 16.6%, only hand imitation significantly improved the model [by an additional 9.6%: for the two-factor model, Odds Ratio = .89, $p = .02$ for VMI; Odds Ratio = .49, $p = .02$ for hand imitation] suggesting that these were the only two factors that could usefully distinguish participant groups.

To further investigate the deficit in hand imitation, the reasons behind the failure of hand imitation tasks was explored. Following the hypothesis of Goldenberg and Hermsdorfer (2002), body part orientation errors but not form or rotation errors, were hypothesized to predict group membership. A stepwise logistic regression predicting group from three classes of errors was performed. The analysis established that the inclusion of body part orientation errors improved prediction accuracy over the null model by 23.8%, to 78.6%, with no other variables making a significant contribution [Odds Ratio = 2.91, $p = .004$].

Task Performance Across Gesture Types

Having established that task performance could predict experimental group, group performance on each of the tasks was examined. This analysis was conducted for comparison with analyses of meaningful gestures (see Chapters 5 and 6) and to explore in more detail each group's performance on the tasks.

The first step in the logistic regression analysis was to fit a model testing the main effects of group, task, and group and task interaction (group x hand or finger imitation). The interaction term for group and task was not significant; therefore it was not used in subsequent analyses ($p = .55$). Next, a second model was fitted to determine if performance differences were detected between hand and finger imitation. Although TD children had a higher success rate for both hand *and* finger imitation [OR = 3.5, $p < .001$], there was not a difference between the average performance of hand and finger imitation in the two groups [OR = .81, $p = .37$]. Hand imitation was performed worse than finger imitation but the differences were not statistically significant. See Fig. 5.1 for the probability of

success in tasks of hand and finger imitation. The probabilities are spaced on a log scale and the lines represent the group means across tasks.

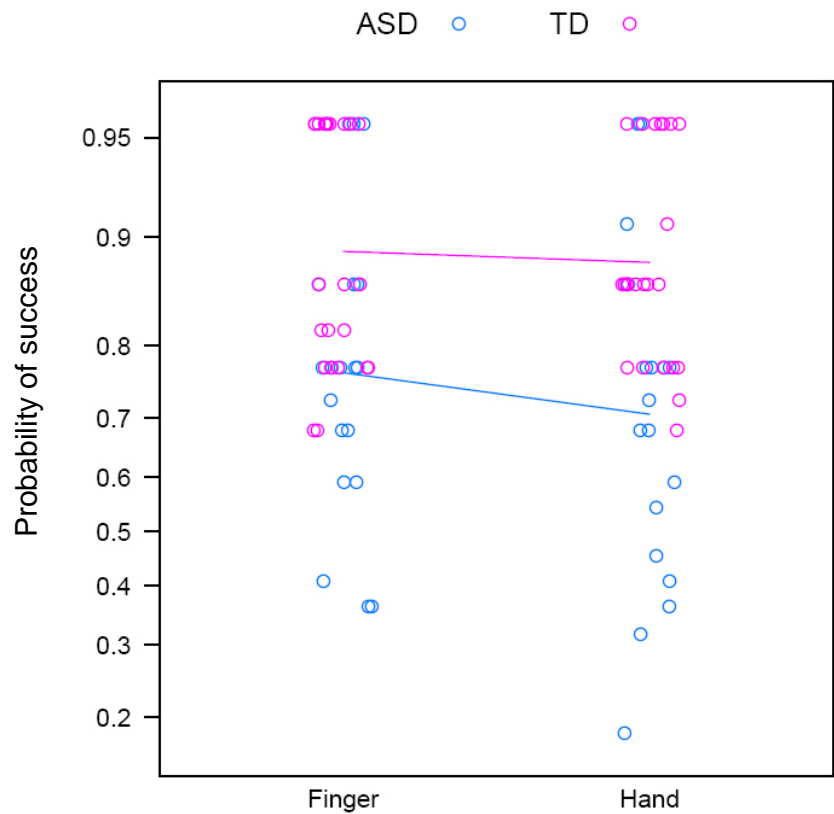


Figure 5.1. Probability of Success in Finger and Hand Imitation in the ASD and TD groups.

Once it was determined that hand and finger imitation did not statistically differ from one another, the underlying cognitive mechanisms potentially influencing performance of hand and finger imitation were evaluated. The cognitive variables added to the model included hand and finger *matching*, Visual Motor Integration, Visual Perception, FSIQ, Digit Recall, and Word List Matching. The follow-up results revealed that group [$F_{1,68} = 5.40, p = .02$] and VP [$F_{1,68} = .004$] were predictive of imitative success. However, the effect of visual perception appeared to be different for the two tasks [Task * VP = $F_{1,68} = 10.16, p = .002$]. No additional task and cognitive variable interactions were identified and only one

cognitive variable and group interaction was uncovered [Group * Finger Match = $F_{1, 68} = 5.07, p = .03$].

Therefore, to investigate the effect of the task-dependent covariates using the same model, the covariates were estimated separately in the ASD and TD groups. The results from the final model, in which all main effects and significant interactions were included, are provided in Table 5.2, higher odds ratios indicate higher odds of success. Overall, typically developing children had greater success performing hand and finger imitation than autistic children [OR = 2.2, $p < .001$], and hand and finger imitation were not significantly different from one another [OR = .86, $p = .53$]. Tasks of Visual Motor Integration, Word List Matching, FSIQ, and hand matching did *not* significantly contribute to imitation success in either the TD or ASD groups. Visual motor integration (VMI) was not associated with higher odds of imitative success for the meaningless gesture tasks, even though VMI successfully predicted group. This provides strong evidence that while visual motor deficits are observed in individuals with autism, the imitation deficits are not explained by motor difficulties alone. Listening Recall was associated with increased success of *hand* imitation but not *finger* imitation. Finger matching was associated with higher performance of *finger* imitation but not *hand* imitation, and this effect was slightly stronger in the TD group. Higher scores in Visual Perception were associated with *lower* success in the finger task, and higher scores in Digit Recall were associated with *lower* success in the hand task. See Table 5.2 for a model summary.

Table 5.2
*Results of the Final Model of Logistic Regression Analysis Including
the Main Effects and Interactions*

Independent and Cognitive Variables	Task	Odds Ratios	p-value
Group	ASD	1.00	reference
	TD	2.20	<.001
Matching	Hand	1.10	.111
	Finger	1.00	reference
Task	Hand	.86	.53
	Finger	1.00	reference
Word List Matching		.99	.115
Visual Motor Integration		1.00	.61
Full Scale IQ		1.00	.72
Interactions			
Finger Match	Finger Imitation	1.20	.01
	Hand Imitation	.96	.67
Finger Match	TD	1.50	.003
Visual Perception	Finger Imitation	.81	.006
	Hand Imitation	1.10	.22
Listening Recall	Finger Imitation	1.00	.56
	Hand Imitation	1.00	.004
Digit Recall	Finger Imitation	.99	.114
	Hand Imitation	.96	<.001

Error Pattern Analyses for Meaningless Gesture Imitation Tasks

To investigate the errors contributing to the meaningless gesture imitative performance, the percent of gestures with specific error types among all gestures with errors, were calculated and binomial regression models were used to compare the error rates between the two groups. The following codes were used for hand posture errors: rotation error, form error, and body part orientation error. The finger imitation errors did not include body part orientation errors because only the hand was vulnerable to that specific error type. Although the individuals with autism made more errors overall than the typically developing controls, there was not a between group main effect of a specific error type for either hand or finger imitation when the percent of gestures with specific error types among all gestures with errors were calculated. See Tables 5.3-5.4 for results of error rates for imitation of meaningless gestures including both hand postures and finger positions.

Table 5.3
Descriptive Statistics for Error Rates in Hand Imitation

	ASD (N=17)		TD (N=14)		Statistic	p-value
	# errors	% given type	# errors	% given type		
Rotation	3.6 ± 2	2.8 ± 6	1.5 ± 1	2.9 ± 11	$F_{1,29} = 0.03$	0.862
Form	3.6 ± 2	21.9 ± 31	1.5 ± 1	12.1 ± 21	$F_{1,29} = 4.16$	0.051
Body Part Orientation	3.6 ± 2	91.2 ± 21	1.5 ± 1	92.1 ± 20	$F_{1,29} = 0.05$	0.832

Note. Percent of gestures with the specific error type among all gestures with an error (mean ± SD). ASD = Autism Spectrum Disorder, TD = Typically Developing Group.

Table 5.4
Descriptive Statistics for Error Rates in Finger Imitation

	ASD (N=16)		TD (N=13)		Statistic	p-value
	# errors	% given type	# errors	% given type		
Rotation	3.0 ± 2	29.8 ± 39	1.8 ± 1	42.3 ± 45	$F_{1,27} = 0.02$	0.888
Form	3.0 ± 2	72.7 ± 38	1.8 ± 1	60.9 ± 41	$F_{1,27} = 0.05$	0.833

Note. Percent of gestures with the specific error type among all gestures with an error (mean ± SD). ASD = Autism Spectrum Disorder, TD = Typically Developing Group.

Correlations and Relationships

To determine how hand and finger imitation performance was associated in individuals with autism and the TD group, bivariate correlations were performed between hand and finger imitation in both the ASD and the TD groups (see Fig. 5.2). The associations were not significant in either group [ASD: $r_{19} = .287$, $p = .23$; TD: $r_{23} = .142$, $p = .52$]. This lack of association between hand and finger gestures in both autism and TD groups could suggest that these two measurements are dependent upon different physiological mechanisms which may be differentially affected in this developmental disorder. This idea was also supported by the finding that there was much variation in performance even within the autism group. See Fig. 5.2 for the relationship between performance in tasks of hand and finger imitation. The probability of success is spaced on the log scale.

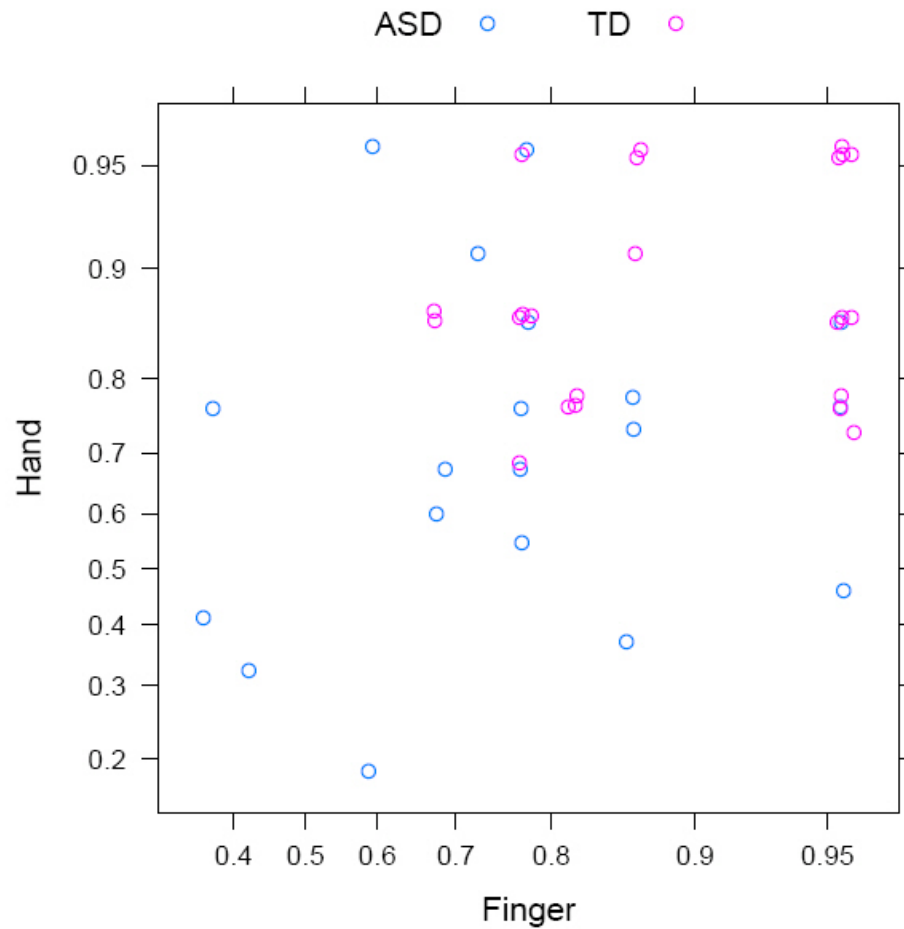


Figure 5.2. The Relationship Between Performance on Tasks of Hand and Finger Imitation

Age as a Predictor of Outcome

The autism and the typically developing control groups were age-matched, thereby controlling the effect of age on the outcome. However, to confirm that age alone did not account for the imitative performance of the ASD group, bivariate correlations were performed in both groups, comparing age with the results on the two imitation tasks. The associations were not significant for hand or finger imitation in either the ASD or TD groups [ASD: age and hand $r_{19} = .128$, $p = .602$; age and finger $r_{19} = .332$, $p = .166$; TD: age and hand $r_{23} = .375$, $p = .078$; age and finger $r_{23} = .143$, $p = .515$].

Although the age of the participants was taken into consideration during group matching, autism is a neurodevelopmental disorder and recent research has identified a pattern of gestural development in other developmental populations (Zoja et al., 2002; 2004), so a follow-up logistic regression model was fitted that included age as a cognitive variable. The results indicated that overall, typically developing children had greater success performing hand and finger imitation than the individuals with autism; however, this finding decreased [from $OR = 2.2$, $p < .001$ to $OR = 1.9$, $p = .006$] when age was included in the model. Hand and finger imitation tasks were still not significantly different from one another [$OR = .76$, $p = .25$] although the higher age is associated with *lower* success in the finger task [$OR = .74$, $p = .005$] and somewhat higher in the hand task, although it did not reach statistical significance [$OR = 1.10$, $p = .05$]. Increased performance in finger matching remained associated with higher scores in finger imitation, but not hand imitation. Higher digit recall also remained associated with poorer success in hand imitation. Differing from the model fitted before the inclusion of the age variable, visual perception was no longer associated with poorer performance in finger imitation and listening recall was no longer associated with an increase in performance in finger imitation.

The Effect of the ADOS and SCQ on Imitation Success of Meaningless Gestures

To explore the effect of ADOS and SCQ performance on the imitation success, two separate models were used to test for an interaction between ADOS and task and SCQ on task. Since no interaction was found, an additive model measuring the effect of ADOS and SCQ on gesture imitation was fitted. The results indicated that higher scores in the SCQ (more autistic characteristics) were associated with lower success in the meaningless gesture imitation tasks but the effect of ADOS did not reach statistical significance [$p = .825$]. See Table 5.5 for results of the effects of ADOS and SCQ on imitation of meaningless gestures.

Table 5.5
Effect of SCQ on Imitation of Meaningless Gestures

Final Model	OR	p-value
Task		
Hand imitation	.71	.31
SCQ	0.93	.019

5.1.4 Discussion

As a group, the individuals with ASD achieved lower scores in hand and finger imitation, hand and finger matching, tasks of visual motor integration, and tests of working memory (word list matching and listening recall) than their typically developing peers. Results indicated that TD children have greater success performing hand and finger imitation than autistic children, although hand and finger imitation did not significantly differ from one another in either the ASD or the TD control group.

Moreover, after analysing the main effects of the cognitive variables within the model, it was clear that not all of the covariates that predicted group membership in the initial stepwise logistic regression contributed to the success of the imitation of meaningless gestures. This is an important distinction, because between-group results of various tests may be significantly different from each other, whilst these same cognitive variables may not accurately reflect the underlying mechanisms associated with successful performance. In the case of meaningless gesture imitation, it was established that visual motor integration, word list matching (a test of working memory), full scale intelligence, and hand matching did not contribute to the odds of successful imitation of either group, whilst visual perception, listening recall, and finger matching were predictive of imitation performance.

Upon closer inspection, an interesting association emerged: *finger matching* was associated with higher performance on *finger imitation* but not on hand imitation,

and this effect was stronger in the typically developing children than the autistic individuals. The association between finger matching and performance of finger imitation follows Goldenberg's theory purporting that these tasks both recruit right hemisphere cognitive mechanisms to perform. This finding suggests that there may be an association between finger matching and finger imitation in typically developing children that is not as well established in individuals with autism, and that the autistic children may not be recruiting underlying cognitive mechanisms in the same way as the TD children to successfully perform the same task.

Another finding revealed that increased finger matching was associated with *higher* finger imitation success, especially in the TD group whilst a task of visual perception was not associated with higher finger imitation success. One way to reconcile this discrepancy is to compare the two tests of visual perception. The Beery test of VP is a measure of the integration of visual perception *and* motor skills, while the finger matching task is strictly a visual perceptual task. Moreover, the task stimuli differed from one another. The matching task included photos of different people taken from different angles and required perceptual skills to discriminate the subtle differences. The Beery VP test did not include any photos of people, but instead used shapes and objects of increasing complexity. Possibly, not all visual perceptual skills affect imitation equally. One prediction may be that adding the human element to the photos of the people was a better predictor of imitation of other people than tasks measuring perception of shapes and objects. Further, visual perceptual skills appeared to affect gesture types differently; in this case *higher* finger matching was a predictor of finger imitation but not hand imitation especially in the TD group. Therefore these findings follow Goldenberg's theory that a test of visual perceptual test would predict finger imitation.

Conversely, listening recall was associated with increased success in hand imitation but not finger imitation. Tests of working memory have been shown to affect pantomime production in adults with limb apraxia (Bartolo et al., 2003), but to date, have not been shown to be a predictor of meaningless gesture imitation

success. Goldenberg's theory suggests that hand imitation is more prone to errors of conceptual mediation, or knowing where the hand is in relationship to the other body parts, whereas the finger imitation does not require that type of knowledge to perform. Whether or not working memory could affect the performance of the hand position in tasks requiring conceptual mediation is an interesting theory and has yet to be investigated. Importantly, although finger matching and listening recall appear to have had an effect on the outcome of imitation performance in both individuals with autism and the TD group, when considered together they are unable to fully explain the imitation deficits observed in the ASD group.

A higher score in digit recall being associated with lower performance in hand and finger imitation is a counterintuitive finding and not easily explained. Perhaps a higher score in a rote recall task such as digit recall may be associated with more autistic-like traits and subsequently predict poorer imitation skills. However, in the digit recall task, the individuals with autism did not outperform any of the participants in the TD group (See Table 4.2 for the range, mean, and standard deviation). Moreover, after analysing associations between digit recall in the TD group and digit recall in the ASD group, there were not any significant findings.

The effect of age on hand and finger imitation differed. Higher age was associated with *lower* success in the finger imitation task whilst an increase in age was associated with an increase in performance in the hand imitation task (trending towards significance). These effects are unexpected and intriguing, but they need to be confirmed in future studies.

Finally, analyses of the error types was conducted to explore the underlying contributing factors to the failures of hand and finger imitation in individuals with autism. Goldenberg's theory suggests that *hand imitation* requires the knowledge of spatial relationships as well as an understanding of the relationship of the body parts to one another. Although the individuals with autism performed more body part orientation errors overall than the typically developing controls, the error rates did not reach statistical significance. Not all of the typically developing

participants made errors when imitating hand postures, so there may have not been enough power to reveal statistical differences.

In summary, the results of the hand and finger imitation and matching tasks revealed that in all tasks, the performance of the autistic group was well below that of their typically developing peers. Moreover, it appeared that in some tasks, the TD children were assisted by different cognitive processes than the individuals with autism, and that the cognitive variables were differentially associated with either hand imitation or finger imitation performance. Taken together, these findings are striking, suggesting that hand and finger imitation are task dependent and that the underlying cognitive mechanisms subserving hand and finger imitation may differ.

5.2 IMITATION OF MEANINGFUL GESTURES

5.2.1. Introduction

In recent years, imitation research has focused on two clinical groups in particular: Individuals with autism spectrum disorder (ASD) and adult patients with limb apraxia. As defined in Chapter 3, limb apraxia is a deficit of processing purposeful movements, unexplained by sensory or motor deficits. In the paediatric literature, the term developmental dyspraxia is often used in place of the term apraxia. Disentangling imitation and praxis is potentially an important area of research in autism, and one that may further inform the understanding of underlying cognitive mechanisms necessary for successful imitation.

Traditionally, imitation in autism has been investigated in the context of cognitive theories (see Chapter 2 for a review). The mirror neuron theory extended the self-other mapping hypothesis, implicating the faulty development of the mirror system in imitation impairments in individuals with ASD. There are reasons to believe that

mirror neurons are also present in humans; indeed, functional neuroimaging studies have provided evidence that the prefrontal cortex may be involved in a “motor resonance” between the observation of an action and the execution of the same action (see Rizzolatti & Craighero, 2004, for a review). If the observation of an action involves part of the system (i.e., mirror neuron system, MNS) involved for executing the same action, then the MNS system may play a role in imitation. As a consequence, it has been proposed that the imitation deficit in individuals with autism may be the result of abnormal mirror neuron development that in turn, is also responsible for the noted deficits in self-other mapping, as well as the impairment in social cognitive skills (Oberman & Ramachandran, 2007; Williams et al., 2001).

Williams and colleagues (2001) predicted specific patterns of imitation deficits in individuals with autism based on the MNS hypothesis; specifically, worse performance in the imitation of meaningless gestures (those not recognised as familiar); better imitation of actions with objects (possibly as a result of object affordances); and the presence of reversal errors (“recreating the hand view that they see instead of translating the perspective the other had seen”), (Williams et al., 2001, p. 8). However, recent research has highlighted discrepancies in these predicted patterns of imitation performance according to the MNS theory, including intact gesture recognition in individuals with autism (Hamilton et al., 2007; Hamilton, 2008; Leighton, Bird, Charman, & Heyes, 2008). In addition, recent studies have published findings that imitation performance in autism appears to be task dependent and researchers have suggested that imitation should not be studied as a “single cognitive or neural system” (Hamilton et al., 2007, p. 1867). Moreover, observations that specific error patterns reported in individuals with ASD are similar to those in adult patients with limb apraxia, have prompted researchers to consider whether these fractionations within the gestural system in ASD may be more parsimoniously explained by a disorder of praxis processing, or apraxia and not the mirror neuron system alone (Mostofsky et al., 2006).

Recently Buxbaum and colleagues (2005) found a correlation between the recognition and imitation of pantomimes in patients with limb apraxia, in line with

the MNS theory. However, some single case studies of limb apraxia have found dissociations between gesture recognition and imitation. In particular, the discovery that patients with lesions in the parietal lobe present with both recognition and imitation errors whereas patients with anterior lesions demonstrate only imitation deficits and not recognition errors provided the foundation for the first cognitive neuropsychological model of praxis processing in adults (Rothi et al., 1991). This dual-route model allows for two independent routes of gestural processing; one responsible for the processing of meaningful gestures along the lexical route, and the other for the processing of meaningless gestures along the non-lexical route (Cubelli et al., 2000; Rothi et al., 1991). This model has been useful to describe some patterns of impairments in limb apraxia population, and it also helped in accounting for a case described by Bartolo et al. (2000). The authors reported a case of a patient, MF, who showed a spared ability to recognise meaningful gestures coupled with an impaired ability to imitate the same gestures (Bartolo et al., 2001). The imitation deficit was not accounted for by a specific gesture reproduction disorder or motor impairment since the patient could imitate *meaningless* actions flawlessly. The authors suggested that once a gesture is recognised as familiar, it is imitated using the long-term memory information stored along a semantic (lexical) route; if it is not recognised as familiar it will be imitated through a mechanism that converts the visual information into a motor act (non-lexical route, Bartolo et al., 2001; Cubelli et al., 2006). Since the patient was also impaired in producing meaningful gestures on command, her lexical route was supposedly impaired at some point after the gestures were recognised.

Similarly, some studies suggested that individuals with autism do not demonstrate any gestural recognition impairments, but do show imitation deficits (Hamilton et al., 2007; Smith & Bryson, 2007). The findings that both limb apraxia patients and individuals with autism, lack an association between gesture recognition and imitation, go against the MNS hypothesis and support instead the hypothesis that gesture recognition is not sufficient for its imitation. According to the dual-route model, reproduction could instead depend upon a lexical route that can be affected

even after the gesture is recognised.

In the present study, praxis processing in a group of individuals with autism was assessed by administering tasks of recognition (i.e., discrimination) and imitation using transitive (i.e., actual object use), intransitive gestures (e.g., social gestures, like “waving”), and pantomimes (i.e., a gestures that describe the object use) to explore the MNS theory and the dual-route hypothesis. If the ability to recognise gestures partly relies on the same mechanism for its imitation, as would be predicted by MNS theory, a correlation between recognition and imitation of gestures would be expected. If the imitation of meaningful gestures relies on two routes (a lexical route when gestures are recognised and non-lexical route when they are not recognised), then a correlation between recognition and imitation is not expected.

More specifically, impaired skills in social communication are well-documented in individuals with autism (Kanner, 1943; Asperger, 1944, cit. in Mayes, Calhoun, & Crites, 2001; Wetherby, Prizant, & Schuler, 2000); therefore, by employing tests of meaningful gesture recognition and imitation (transitive, intransitive and pantomime), the first prediction is that individuals with autism will be more affected in the recognition of *intransitive* than in *object related* gestures (transitive and pantomimes). Following, in line with the MNS hypothesis, impaired gestures recognition would be followed by difficulties in gesture imitation, whereas according to the dual-route models of cognitive processing in limb apraxia, intransitive gestures will be imitated as if they are meaningless, thus using the non-lexical route. For this reason, a correlation between the recognition and the imitation of intransitive (social) gestures is not expected. However, a correlation between the recognition and imitation of object-related gestures such as pantomimes or object use (transitive gestures) is predicted. Finally, several possible underlying cognitive functions that may influence imitation performance, including visual perception (VP), visual motor integration (VMI), intelligence, and tests of working memory [digit recall (DR), word list matching (WLM), and listening recall (LR)] were included in the

assessment.

5.2.2 Method Review

Three meaningful gesture imitation experimental tasks were included: Imitation of transitive gestures, intransitive gestures, and pantomimes (see Appendix A for the description of the stimuli). Twenty dynamic stimuli for each type of imitation task were presented via laptop computer. The participants sat across from the computer while they viewed twenty videoclips of each gesture category (giving a total of 60 imitation videoclips). Each videoclip consisted of a child actor producing a gesture. The participants were instructed to imitate the gesture after viewing each videoclip. Each gesture type was tested in blocks: 20 videoclips of transitive gestures; 20 videoclips of intransitive gestures; and 20 videoclips of pantomimes. The participants were videotaped while they produced the gestures, for coding purposes. Each gesture was recorded and subsequently coded by two raters, one of whom was blind to the experimental hypothesis and the other was one of the authors (H.S.H.). For each correct performance, participants received a score of 1, thus participants who did not commit any errors received a maximum score of 20 out of 20 trials per gesture type. A coding system was designed to measure the number and types of errors present during the production. For example, if a participant demonstrated a hand error, they did not receive credit for a correct response for that trial, in addition to receiving an error tally for the particular error type. The codes were a combination used in adult apraxia literature (Bartolo et al., 2008; Buxbaum et al., 2005) and autism (Rogers et al., 1996).

The pantomime recognition task, adapted from Bartolo's Apraxia Battery, was based on tests of recognition from adult neuropsychological studies. Twenty dynamic stimuli for pantomimes were presented via laptop computer. The participants sat across from the computer while they viewed twenty videoclips of pantomimes. Each videoclip consisted of a child actor producing a gesture. The participants were instructed to determine if the person in the videoclip was

performing the pantomime correctly or incorrectly, by stating 'yes or no' after viewing each videoclip. Each gesture type was tested in blocks: The participants watched 20 videoclips of children performing pantomimes and they were required to state if the pantomime was performed correctly or incorrectly. For each correct answer, participants received a score of 1, thus participants who did not commit any errors in recognition received a maximum score of 20.

5.2.3 Results of Meaningful Gestures

Approach to Analysis

The recognition and imitation data analyses were performed in five consecutive steps: 1) evaluating group differences in task performance, 2) comparing task performance across gesture types in both groups, 3) predicting underlying cognitive mechanisms necessary for recognition and imitative performance, 4) assessing error types and 5) exploring correlations and relationships between recognition and imitation tasks.

Hand Choice

Paired sample t-tests were performed for each imitation type to determine if any differences in the two attempts could be attributed to practice effects. There were no effects for either transitive gestures or pantomimes, but order effects were observed in intransitive gesture imitation in the autism group only [$t_{18} = 3.2$, $p = .004$, Cohen's $d = .70$]. However, since this effect was opposite what would have been predicted by practice, all three gesture types were collapsed across the first and second attempts.

Group Differences

Welch's independent t-tests were used to determine group differences in the performance of recognition and imitation tasks for all three gesture types. Welch's t-tests were selected over Mann-Whitney U tests as the analysis of choice to account for the unequal variances in the tested samples. *T-tests* showed significant between-group differences in recognition, revealing poorer performance of the autism participants in all tasks of recognition [transitive gestures $t_{39.9} = -4.77$, $p < .001$, Cohen's $d = -1.54$; intransitive gestures $t_{27.09} = -5.20$, $p < .001$, Cohen's $d = -1.63$; and pantomimes $t_{22.68} = -2.53$, $p = .019$, Cohen's $d = -.76$. All three recognition tasks resulted in large effect sizes. See

Table 5.6 for the group results of the recognition and imitation tasks. Similarly, the TD group outperformed the ASD group in all the three tasks of *imitation*: [transitive gesture imitation $t_{18,9} = -6.52$, $p < .001$, Cohen's $d = -2.17$; intransitive gestures $t_{19,8} = -7.40$, $p < .001$, Cohen's $d = -1.29$; and pantomime imitation $t_{21,2} = -7.88$, $p < .001$, Cohen's $d = -2.5$].

Table 5.6
Results Achieved for the Recognition and Imitation Tasks by the Autism Spectrum Disorder (ASD) and Typically Developing (TD) Groups.

	ASD (N = 19) (mean \pm SD)	TD (N = 23) (mean \pm SD)
Recognition		
Object Use***	18.16 \pm 0.69	19.26 \pm 0.81
Intransitives***	14.11 \pm 2.35	17.26 \pm 1.32
Pantomimes**	15.95 \pm 3.47	18.09 \pm 1.39
Imitation		
Object Use***	12.37 \pm 4.52	19.22 \pm 0.80
Intransitives***	13.05 \pm 3.73	19.54 \pm 0.92
Pantomimes***	9.32 \pm 5.03	18.83 \pm 1.66

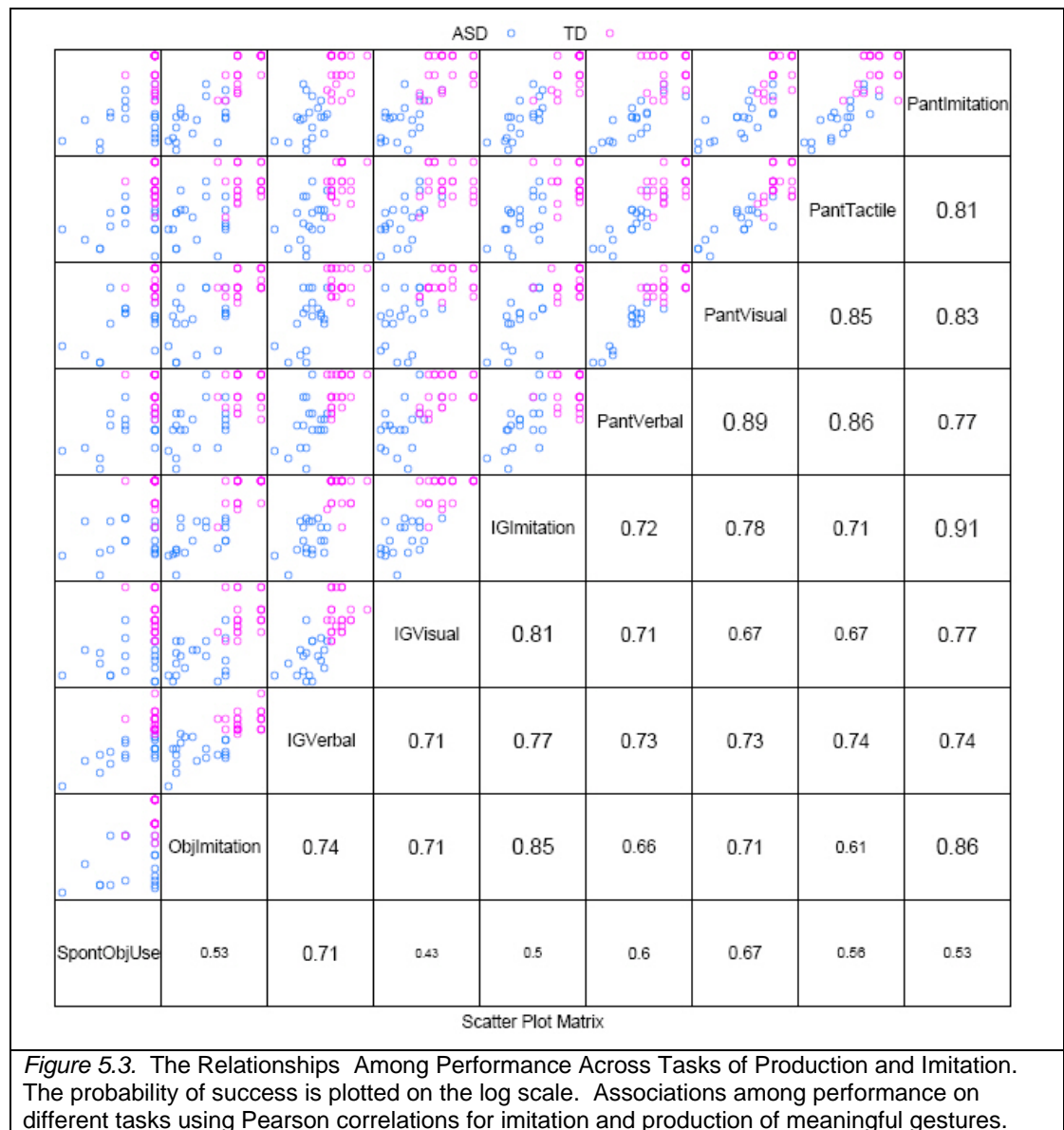
Note. *** $t < .001$; ** $t < .01$. Asterisks indicate differences between groups.

Predicting Group

In the *meaningless* gesture experiment, the first analysis established which variables best accounted for group differences; all six variables described above (visual motor integration; visual perception; hand and finger matching, hand and finger imitation) were entered into a stepwise logistic regression predicting group membership. However, in the *meaningful* gesture experiments, this analysis was not conducted due to the multicollinearity of the variables.

First, a scatterplot matrix was made of the log-odds of success of the various tasks. The upper panels show the scatterplot, whilst the lower ones provide the Pearson correlations. Except for spontaneous object use, all of the measures were highly correlated, especially the different modalities within the same task. The separation between the ASD and TD groups was also striking. See Fig. 5.3 for

Pearson correlations for imitation and production of meaningful gestures.



Task Performance Across Gesture Types

Recognition Tasks

A logistic (binomial) regression model was fitted to determine whether there was an effect of autism and/or an effect of task in the recognition performance of the

three types of tested gestures in the ASD and control groups. In other words, since a significant between-group difference was already identified, the next step was to determine if all of the tasks were performed equally. A simple model was fitted including group, task, and an interaction code. Once it was determined that no group-task interaction was evident, an additive model was used. Next, the cognitive variables were added to the model to examine the effect of task, group, and cognitive variables on the odds of successful recognition. No group-task interaction was evident and only one each of cognitive predictor-task and cognitive variable-group interaction was found to be significant. The results from the final model, in which all main effects and the significant interactions were included, are provided in Table 5.7; high odds ratios indicate higher odds of success.

The analyses used pantomime recognition as the reference to compare the tasks to each other. The odds of successful recognition among typically developing children were 2.3 fold higher than among autistic children. Intransitive gesture recognition was the most difficult ($OR = .62$, $p = .001$ as compared to pantomime), followed by pantomime recognition and object recognition ($OR = 2.6$, $p < .001$) tasks. Pantomime and object recognition were not significantly different from each other. This effect was similar in both groups although the individuals with autism performed all tasks more poorly than the controls. This difference was the same for all the tasks, and was present even when adjusting for the cognitive variables.

The addition of the underlying cognitive variables revealed that digit recall affected the success of different tasks unequally ($p = .009$ for interaction). Specifically, intransitive gesture and object recognition were not affected by changes in digit recall; however success in pantomime recognition decreased as DR increased. VMI, on the other hand, appears to have had a different effect in the two groups ($p = .02$ for interaction): among children with ASD, VMI did not affect the success rate, however among TD children, higher VMI was associated with lower odds of success. The remaining cognitive variables (VP, Listening

recall, FSIQ, and WLM) did not appear to affect the odds of successful recognition. See Table 5.7 for the effect of the cognitive variables on recognition of meaningful gestures.

Table 5.7
Effect of Cognitive Variables on the Recognition of Meaningful Gestures included in the Final Model

		Odds Ratios	p-value
Task	Pantomime	1.00	reference
	Intransitive Gestures	0.62	.001
	Transitive Gestures	2.6	<.001
Group	ASD	1.00	reference
	TD	2.3	<.001
Cognitive Variables			
VP		1.00	.70
LR		1.01	.14
FSIQ		1.00	.53
WLM		1.00	.68
DR	for Pantomime	0.98	.005
	for IG	1.00	.68
	for Object	1.00	.85
VMI	within ASD	1.01	.27
	within TD	0.98	.04

Task Performance Across Gesture Types

Imitation Tasks

A second model of logistic (binomial) regression was conducted to assess whether there was an effect of autism and/or an effect of task in the performance of the three types of tested *imitation* in the ASD and control groups. This analysis was similar to the recognition model and compared the tasks to each other using pantomime imitation as the reference for comparison. The analysis began with a simple model containing only group, task and their interaction. No group-task interaction was evident, so an additive model was used. The results of this

analysis revealed a large group difference, as well as smaller but significant differences among tasks. The odds of successful imitation among typically developing children were 19.0 fold higher than among autistic children ($p < .001$). The results indicated that even though the autism group performed all of the imitation tasks more poorly compared to the controls, there appeared to be a difference in how both groups imitated across tasks. In this case, pantomime imitation was performed more poorly than imitation of transitive and intransitive gestures. The odds of successful pantomime imitation were lower than the other gesture types, with both object ($OR = 1.86, p = .003$) and intransitive gesture imitation ($OR = 2.30, p < .001$) having higher success rates (see Fig. 5.4).

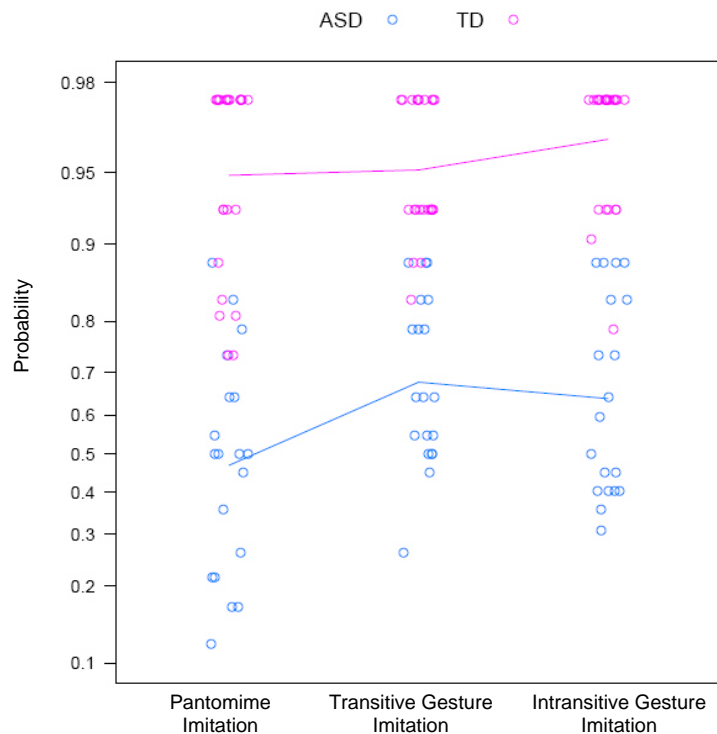


Figure 5.4. Task performance across gesture types for the ASD and TD groups

The effect of task, group and cognitive variables on the odds of successful imitation was also examined. No group-task, or cognitive predictor-task interactions were

found, and only one cognitive variable-groups interaction was found to be significant. The results from the final model, in which all main effects and the significant interactions were included, are shown in Table 5.8 below; high odds ratios indicate higher odds of success.

Table 5.8
Effect of the Cognitive Variables in the Final Model For Imitation of Meaningful Gestures.

Imitation		Odds Ratios	p-value
Task	Pantomimes	1.00	reference
	Intransitive Gestures	2.30	<.001
	Transitive Gestures	1.90	.003
Group	ASD	1.00	reference
	TD	19.0	<.001
Visual Perception		1.10	.004
Listening Recall		1.04	.004
Digit Recall		0.99	.005
Word List Matching		1.00	.50
Visual Motor Integration		0.99	.26
Full Scale IQ	within ASD	1.00	.96
	within TD	0.96	.02

Interestingly, this effect and overall pattern of performance is similar in both groups, and is not affected by the cognitive variables. Although the overall difference in performance was not fully explained by the cognitive measures; higher Visual Perception and Listening Recall scores were associated with higher odds of success, whilst higher DR scores were associated with lower odds (see Fig. 5.5). WLM and VMI did not predict successful imitation. These effects are similar for all tasks, and both groups. FSIQ had a different effect in the two groups ($p=.023$ for interaction): among children with ASD, FSIQ does not affect the success rate, however among TD children higher FSIQ is associated with lower odds of success. See Fig. 5.5 for the effect of each cognitive variable on

meaningful gesture imitation. The y axis is the actual probability of success (log scale). The x axis is the results of the measured cognitive variable. Regression lines were fitted for each relationship.

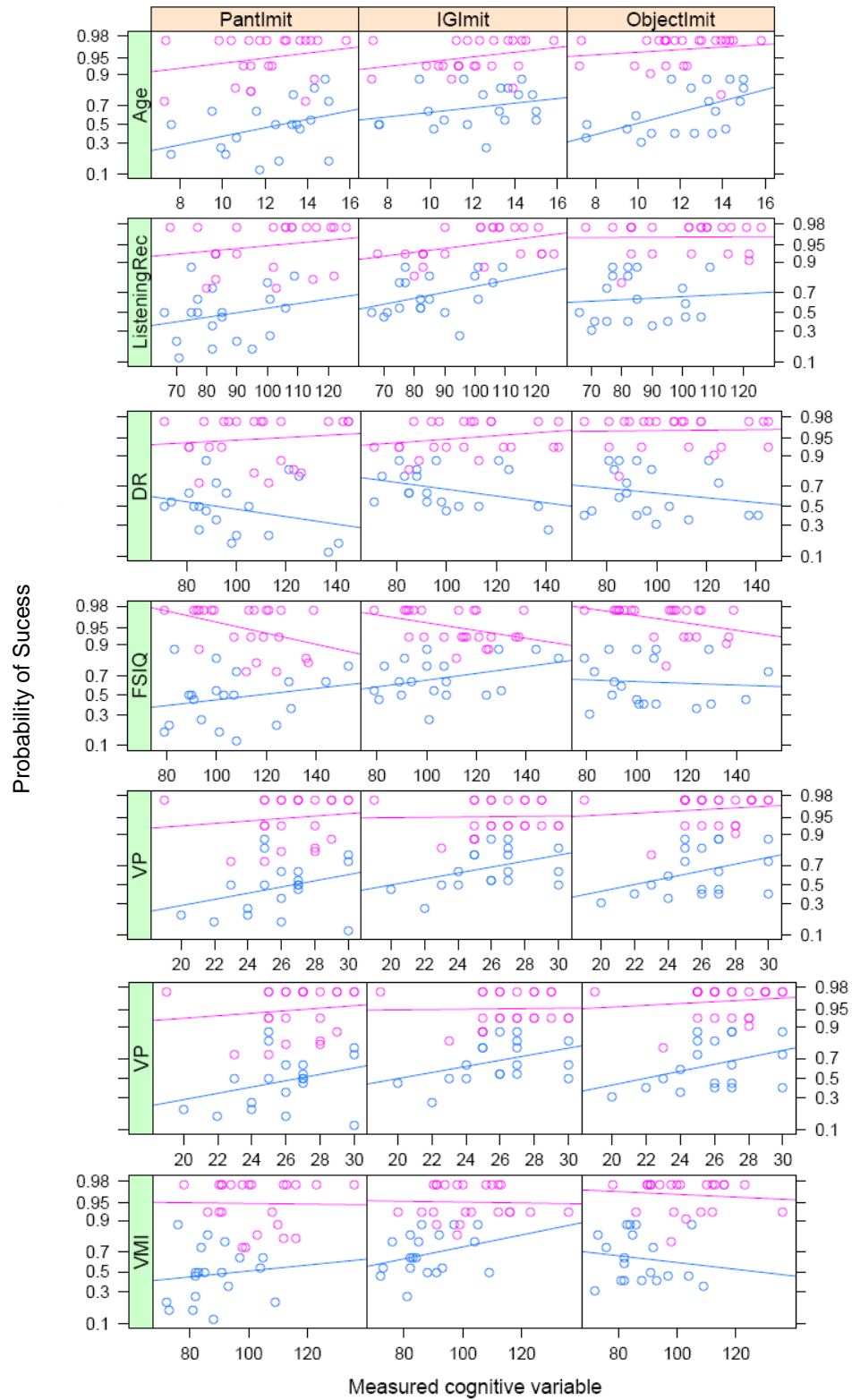


Figure 5.5. Effect of cognitive variables in meaningful gesture imitation.

Error Pattern Analyses for Meaningful Gesture Imitation Tasks

To investigate the errors contributing to the meaningful gesture imitative performance the percent of gestures with specific error types among all gestures with errors were calculated and binomial regression models were used to compare the error rates between the two groups. The following codes were used across all three tasks: hand posture, arm/trajectory, amplitude, timing, and reversal errors. The pantomime errors also included body-part-as-object and distance errors. In pantomime imitation there was a main effect of hand and reversal errors [$F_{1,28} = 5.0$, $p = .034$; and $F_{1,28} = 6.0$, $p = .021$] whereas in intransitive gesture imitation only amplitude errors significantly differed between the two groups [$F_{(1,28)} = .043$]. Similarly to pantomime imitation, significant findings were revealed between groups in hand errors [$F_{1,29} = 8.5$, $p = .007$]. Not all participants in the TD group made errors and only trials with errors could be used for analyses; therefore, low power may have been a factor as to why additional spatiotemporal errors were not statistically different between the two groups (see Tables 5.9-5.11).

Table 5.9
Transitive Gesture Imitation

	ASD (N=17)		TD (N=14)		Statistic	p-value
	# errors	% given type	# errors	% given type		
Hand	7.5 ± 5	35.1 ± 30	1.3 ± 1	70.2 ± 43	$F_{1,29} = 8.48$	0.007
Arm	7.5 ± 5	12.9 ± 16	1.3 ± 1	9.5 ± 28	$F_{1,29} = 0.12$	0.729
Amplitude	7.5 ± 5	0.5 ± 2	1.3 ± 1	0.0 ± 0	$F_{1,29} = 0.79$	0.383
Timing	7.5 ± 5	2.4 ± 5	1.3 ± 1	0.0 ± 0	$F_{1,29} = 3.11$	0.088
Distance	7.5 ± 5	2.4 ± 5	1.3 ± 1	7.1 ± 27	$F_{1,29} = 0.10$	0.751

Note. Percent of gestures with the specific error type among all gestures with an error (mean ± SD). ASD = Autism Spectrum Disorder, TD = Typically Developing Group.

Table 5.10
Intransitive Gesture Imitation

	ASD (N=19)		TD (N=7)		Statistic	p-value
	# errors	% given type	# errors	% given type		
Hand	6.9 ± 4	53.2 ± 22	1.5 ± 1	41.7 ± 46	$F_{1,24} = 0.87$	0.360
Arm	6.9 ± 4	35.2 ± 29	1.5 ± 1	3.6 ± 9	$F_{1,24} = 3.65$	0.068
Amplitude	6.9 ± 4	14.0 ± 13	1.5 ± 1	0.0 ± 0	$F_{1,24} = 4.56$	0.043
Timing	6.9 ± 4	10.9 ± 21	1.5 ± 1	0.0 ± 0	$F_{1,24} = 1.11$	0.303
Reversal	6.9 ± 4	6.4 ± 12	1.5 ± 1	22.6 ± 37	$F_{1,24} = 2.67$	0.116

Note. Percent of gestures with the specific error type among all gestures with an error (mean ± SD). ASD = Autism Spectrum Disorder, TD = Typically Developing Group.

Table 5.11
Pantomime Imitation

	ASD (N=19)		TD (N=11)		Statistic	p-value
	# errors	% given type	# errors	% given type		
Hand	10.7 ± 5	62.7 ± 24	2.5 ± 2	53.0 ± 47	$F_{1,28} = 4.99$	0.034
Arm	10.7 ± 5	52.9 ± 23	2.5 ± 2	22.6 ± 33	$F_{1,28} = 1.20$	0.282
Amplitude	10.7 ± 5	6.1 ± 12	2.5 ± 2	0.0 ± 0	$F_{1,28} = 2.24$	0.146
Timing	10.7 ± 5	3.0 ± 6	2.5 ± 2	9.1 ± 30	$F_{1,28} = 0.00$	0.962
Body Part	10.7 ± 5	5.6 ± 9	2.5 ± 2	1.8 ± 6	$F_{1,28} = 0.07$	0.786
Orientation						
Distance	10.7 ± 5	12.2 ± 14	2.5 ± 2	9.1 ± 30	$F_{1,28} = 1.04$	0.316
Reversal	10.7 ± 5	6.6 ± 8	2.5 ± 2	0.0 ± 0	$F_{1,28} = 5.96$	0.021

Note. Percent of gestures with the specific error type among all gestures with an error (mean ± SE). ASD = Autism Spectrum Disorder, TD = Typically Developing Group.

Correlations and Relationships

To investigate the relationship between recognition and imitation, bivariate correlations were performed separately for the ASD and TD groups. A significant association between pantomime imitation and pantomime recognition was identified in the autism group [$r_{19} = .543$, $p = .01$] but not in the TD group [$r_{23} = .205$, $p = .35$]. However, the difference between the two correlations was not significant ($p = .23$). There was a range restriction in the TD group and little variability between the participants therefore, it is not possible to truly determine

the correlation in the TD group. To compare pantomimes with the other gesture types, the same correlations were performed for transitive and intransitive gesture recognition and imitation in the ASD group, and the results were not significant, suggesting that in ASD there may be a unique relationship between pantomime recognition and pantomime imitation.

Age as a Predictor of Imitation Success

Importantly, the autism and the typically developing control groups were carefully age-matched, thereby controlling the effect of age on the outcome. However, to confirm that age did not affect the imitative performance of the groups, bivariate correlations were performed in both groups, comparing age with the results on the three imitation tasks. In the ASD group, the associations were not significant for intransitive gestures or pantomimes [ASD: $r_{19} = .320$, $p = .18$; $r_{19} = .402$, $p = .08$], but they were significant for the transitive gesture imitation task [$r_{19} = .567$, $p = .01$]. In the TD group, associations were not significant for transitive gestures, intransitive gestures, or pantomimes [$r_{23} = .200$, $p = .36$; $r_{23} = .038$, $p = .86$; $r_{23} = .254$, $p = .242$].

A follow-up logistic regression model was fit that included age as a cognitive variable. The results revealed that although age did have a small but significant effect [OR=1.10, $p = .007$], it could not explain the dramatic difference between the imitative performances of individuals with ASD and typically developing children. The odds of successful imitation amongst typically developing children remained over 19.5 fold higher than amongst autistic children ($p < .001$).

The Effect of the ADOS and SCQ on Imitation Success of Meaningful Gestures

To explore the effect of ADOS and SCQ performance on the imitation success, two separate models were used to test for an interaction between ADOS and task and SCQ on task. Since no interaction was found, an additive model measuring

the effect of ADOS and SCQ on gesture imitation was fitted. The results indicated that lower SCQ (fewer autistic characteristics) scores were associated with higher success but the effect of ADOS did not reach statistical significance [$p = .698$]. See Table 5.12 and Fig. 5.6 for results of the effects of ADOS and SCQ on imitation. Increased behaviours and characteristics typically associated with autism are reflected in *higher* scores in the ADOS and SCQ.

Table 5.12
Effects of SCQ on Imitation

Final Model		OR	p-value
Task	Object Imitation	1.88	.035
	IG Imitation	2.18	.010
	SCQ	0.93	.019

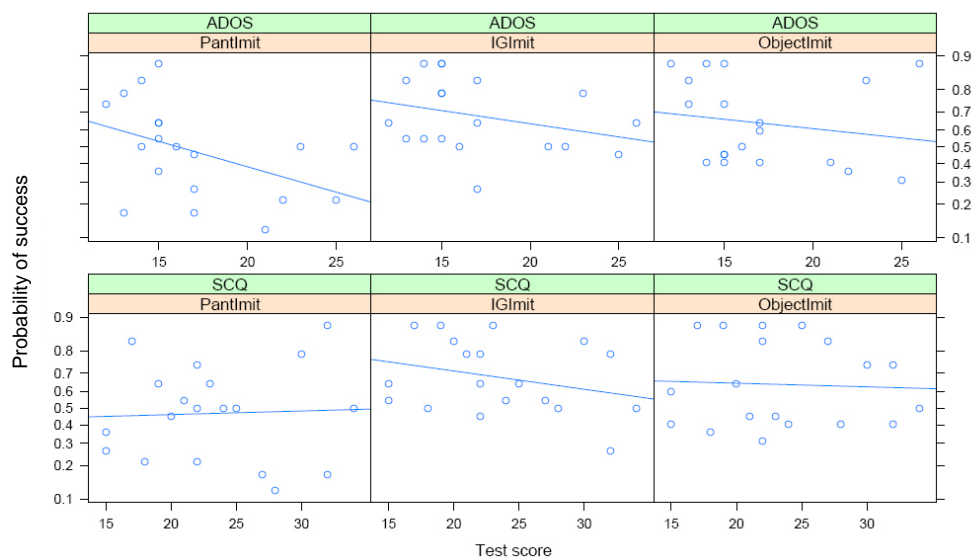


Figure 5.6. The effect of ADOS and SCQ on task performance in the ASD group.

5.2.4 Discussion

The results of this study support previous findings suggesting that there is a

pervasive imitation deficit in individuals with ASD. The individuals with autism demonstrated deficits in the imitation of meaningful gestures across all three tasks. Importantly, the tasks were not all performed equally; a pattern emerged in both the ASD and TD groups, which revealed that pantomime imitation was performed more poorly than imitation of transitive and intransitive gestures. Intransitive gesture imitation had the highest rate of success. This pattern is identical to the one reported in a population of healthy adults (Mozaz et al., 2002; Carmo and Rumiati, 2009).

Similarly, all three gesture recognition tasks were performed significantly more poorly by the ASD group than by the TD group. Contrary to the imitation results, intransitive gesture recognition was shown to be the most difficult task, followed by pantomime and object recognition. Interestingly, this same overall pattern of imitation and recognition performance across tasks was observed in the TD group, suggesting that even in typically developing populations, the performance of imitation tasks may vary depending on the tested gesture type. It is worth noticing that in previous studies testing healthy adults some did not find any difference between the ability to recognise pantomimes and intransitive gestures (Bartolo, 2002), some others found a better recognition of intransitive gestures over pantomimes (Mozaz et al., 2002). On the contrary, in this study both TD and ASD groups performed recognition of intransitive gestures more poorly than the recognition of pantomimes. One reason for this pattern could be that it was an adult who chose the intransitive gestures to be included in the task, involuntarily creating a bias in the attribution of children's communicative gestures. Another reason could be that the ability to recognise communicative gestures may develop at a different rate than object related actions, as suggested by the opposite pattern found in healthy adults (Mozaz et al., 2002).

Although the overall pattern was similar, the TD outperformed ASD in all tasks. The two groups were matched for chronological age, Verbal Intelligence, Performance Intelligence, and Full Scale Intelligence. In addition to the matching measures, preassessment cognitive tests were administered that included tests of

visual perception, working memory, and visual-motor integration. Results of the cognitive tests revealed that the ASD group performed significantly more poorly than the TD controls on measures of visual motor integration (VMI) and two working memory measures (word list matching and listening recall). Group differences were not identified in tasks of visual perception (VP) or digit recall (DR). Thus, group differences in imitation and recognition were re-examined after the cognitive variables were statistically controlled. Group differences could not be accounted for by age, IQ, or performance on cognitive variables such as visual motor and working memory abilities since group difference in imitation and recognition of gestures remained after the cognitive variables were controlled. However, within both groups, better performance on working memory and visual perception tasks were associated with *increased* imitation success.

Past research has identified a relationship between working memory and pantomime imitation (Bartolo et al., 2003). In particular, the authors suggested that working memory abilities allow the semantic information, including the long-term representations and knowledge of how the objects are manipulated, to be maintained on-line allowing for successful pantomime execution. The authors concluded that, as a consequence, a selective deficit in working memory abilities would thereby contribute to a selective deficit in pantomime production (Bartolo et al., 2003).

Conversely, higher scores in FSIQ were associated with lower imitation performance in the TD group alone, whilst higher scores in digit recall were associated with lower imitation performance in both groups. These findings are counterintuitive and would need to be tested in follow-up studies. Perhaps one explanation of the inverse relationship between FSIQ and performance in the TD group is that the higher the FSIQ in the typically developing participants, the less challenging they may have found the tasks, and subsequently they may have lost interest and not put forth their best effort. However, this did not appear to be the case when engaging with the participants during the testing sessions. The other unexpected finding of an increase in performance in the digit recall task being

associated with a decrease in imitation performance is also counterintuitive. As discussed in Section 5.1.4, perhaps a higher score in a rote recall task such as digit recall may be associated with more autistic-like traits and subsequently predict poorer imitation skills. However, in the digit recall task, the individuals with autism did not outperform any of the participants in the TD group (See Table 4.2 for the range, mean, and standard deviation). Moreover, after analysing associations between digit recall in the TD group and digit recall in the ASD group, there were not any significant findings.

To better understand the reasons behind the imitative failures in ASD, the nature and rates of specific error types contributing to the imitation failures were examined. Although the individuals with autism made more errors, the error rate was calculated as the percent of gestures with specific error types among all gestures with errors. After comparing the error rates in both groups, it was determined that the rates differed depending on the imitation task. One specific type of error rate in the ASD group was considered of particular importance because hand configuration errors have been reported to be the most frequent error type in patients with limb apraxia (Buxbaum et al., 2005). The hand error rate statistically differed between the two groups and this finding extended to transitive gestures and pantomimes, both object-related gestures. The results showed that in pantomime imitation there was a main effect of *hand* and *reversal* errors, whereas in intransitive gesture imitation only *amplitude* error rates significantly differed between the two groups. In transitive gesture imitation, *hand* error rates significantly differed between the two groups.

Mostofsky et al. (2006) reported that individuals with ASD and developmental dyspraxia demonstrated more spatial errors than errors in other categories (e.g., body-part-as-object, temporal, and content). In their scoring system, hand errors of internal and external configuration as well as errors of spatial movement and amplitude were collapsed into one category, so direct comparison with these current results is not possible. However, the present findings of errors of the hand (internal configuration) and amplitude (spatiotemporal) follow the findings of Mostofsky et

al. (2006) suggesting that the error rates identified in individuals with autism are characteristic of error patterns identified in developmental dyspraxia.

Williams et al. (2001) also predicted various error patterns including the presence of reversal errors in individuals with autism, considered as further support for the MNS theory. These current findings revealed that the error rates of reversal errors differed significantly between the groups for pantomime imitation but for transitive or intransitive gesture imitation, partially supporting the theory. Another prediction of the MNS hypothesis was that individuals with autism would perform better in imitation tasks of actions with objects, possibly as a result of object affordances. On the contrary, this current study identified *intransitive gestures* as being performed better than object related gestures thereby contradicting these predictions.

Further investigation of the recognition and imitation performance in ASD was undertaken using the theoretical explanations of mirror neurons and models of limb apraxia. The MNS theory suggests that a defective mirror neuron system underlies the imitation deficits so pervasive in individuals with autism (Williams et al., 2001) and addresses impairments in both gestural recognition² and imitation. The hypothesis predicts that the imitation deficits that are important to ‘self and other’ would be observed in individuals with autism; therefore it follows that deficits in both gestural recognition and imitation should be evident. Moreover, evidence of a correlation between pantomime recognition and pantomime imitation has been identified in patients with limb apraxia and the authors suggested that this system is ‘uniquely human’ and is an elaboration of the basic mirror neuron system (Buxbaum et al., 2003; 2005). Further, recent research has provided evidence for automatic imitation of intransitive actions in humans (Press, Bird, Walsh, & Heyes,

²One approach that has been used to test gesture recognition included a matching task requiring the participant to view a picture of a person making an action with the hand missing and choosing a picture of a hand in the best configuration to match the action (Hamilton et al., 2007; Rothi, Ochipa, & Heilman, 1991). Others, have measured gesture recognition by administering a task requiring participants to discriminate correctly from incorrectly executed gestures (Buxbaum, et al., 2005; Cubelli et al., 2000).

2008). In this study, results showed that the individuals with autism performed much more poorly than the TD controls in all tasks of gesture recognition and imitation. However, if the mirror neuron system holds gestural representations that are necessary for both recognition and imitation, then a correlation between the two should be identified for both pantomimes and intransitive gestures. These results revealed a correlation in the ASD group between pantomime recognition and pantomime imitation but not for intransitive gesture or transitive gesture imitation thereby only partly supporting the MNS hypothesis. An association between pantomime recognition and pantomime imitation was not identified in the TD group.

These current results did not fully support the MNS hypothesis so additional theoretical explanations were considered. The relationship between recognition and imitation has also been of interest in limb apraxia research. Even though some single cases showed a dissociation between pantomime (Bartolo et al., 2003) and gesture recognition (Bartolo et al., 2003) and imitation, a group study showed a correlations between pantomime recognition and pantomime imitation (Buxbaum et al., 2005). Moreover, the results indicated that the error rates, correlations, and patterns of gestural processing are similar to those identified in limb apraxia patients.

Therefore, perhaps a more parsimonious explanation of the pattern of recognition and imitation evidenced in the ASD group is grounded in theories of limb apraxia, specifically using a dual-route cognitive neuropsychological approach to gestural processing (Cubelli et al., 2000). According to this model, gestures are processed according to a lexical and a non-lexical route (Cubelli et al., 2000). In particular, it has been found that once a gesture is recognised as familiar it is reproduced using the lexical route. On the contrary, if a gesture is not recognised as familiar, its reproduction will be carried out by a mechanism involved in the transformation of the visual information into motor acts using the non-lexical route (Bartolo et al., 2001). In this current study, the ASD group performed more poorly than the typically developing participants in their ability to recognise intransitive gestures,

suggesting that intransitive actions are not generally well recognised by individuals with autism. On the contrary, object related gestures (pantomimes and transitive gestures) were better recognised than intransitive actions, thus it is proposed that they were processed using the long-term memory representation of the gesture along the lexical route. Given that the typically developing group presented with the same pattern of performance (better recognition of object related gesture than intransitive actions; and better imitation of intransitive gestures than object related gestures), the overall results indicate that the children and adolescents' ability to imitate meaningful gestures could be explained by the cognitive model of gesture processing usually adopted for adults. Indeed, children and adolescents appear to imitate gestures using the most well-developed cognitive route as proposed by the dual-route model of limb apraxia (Cubelli et al., 2000; 2006).

The dual-route hypothesis can also account for the reversed results achieved in the recognition and imitation of gestures (intransitive gesture recognition being performed more poorly than the other gesture types while intransitive gesture imitation was performed the best). According to previous findings (Bartolo et al., 2001), since object related gestures are better recognised, they are presumably processed along the lexical route. However, since intransitive gestures are not well-recognised, they are presumably imitated along the non-lexical route. Given that the ASD group performed worse in all imitation tasks with respect to the TD group, both routes are supposed to be impaired. The ASD group performed better in the imitation of intransitive gestures than object related gestures, suggesting that the non lexical route is better preserved than the lexical one (see also Cubelli et al., 2006). These findings suggest that the individuals with autism present with similar praxis patterns as observed in patients with limb apraxia and therefore cannot be fully accounted for by error patterns attributed to imitation impairments in line with the Mirror Neuron Theory account of imitation in autism.

In summary, the individuals with ASD performed all tasks more poorly than controls, and their imitation performance could not be fully explained by group

differences in the cognitive measures included in the model. This is the first report of significant between group differences across three different types of gestures: transitive, intransitive, and pantomimes. Other studies have often collapsed intransitive gestures and pantomime imitation scores together for analysis and/or not included a test for transitive gesture imitation (Dewey et al., 2007; Mostofsky et al., 2006). Furthermore, an in-depth analysis of the error types along with tests measuring cognitive performance provided insight into the reasons behind the imitation deficits. Deficits in pantomime imitation (Bartolo et al., 2003), findings of hand posture errors including spatial errors (Mostofsky et al., 2006), and associations between pantomime imitation and recognition (Buxbaum et al. 2005; Rothi et al., 1991), have all been demonstrated in patients with limb apraxia. These same characteristics were observed in this sample of individuals with autism. These findings differ from previous reports that individuals with autism do not present with gestural recognition deficits (Hamilton et al., 2007; Smith & Bryson, 2007).

There may be several explanations as to why these findings revealed that the participants with autism demonstrated significant impairments in gestural recognition in three separate tasks. This current study tested three different gesture categories (transitive, intransitive gestures, and pantomimes) that included twenty trials each (for a total of sixty trials of recognition and sixty trials of imitation). Hamilton and colleagues (2007) tested recognition of nine pantomimes and nine symbolic gestures and Smith and Bryson tested recognition of six actions with objects and six communicative gestures. Moreover, the procedures varied across studies. Hamilton et al. (2007) used a matching approach and Smith and Bryson's (2007) procedure included the examiner miming the object and requesting the participant to verbalise a response. Finally, these results suggest that the cognitive processing of gesture imitation in autism is an important area of research, and that the Mirror Neuron Theory of imitation cannot account for all of the patterns of praxis processing evident in individuals with autism.

CHAPTER 6

PRODUCTION OF MEANINGFUL GESTURES ACROSS MULTIPLE MODALITIES

6.1 MEANINGFUL GESTURE PRODUCTION

6.1.1 Introduction

As established in the previous chapter, imitation deficits are a robust finding in individuals with autism, and recent studies suggest that impaired imitation performance in ASD appears to be evident across gesture categories (Hamilton, 2008; Mostofsky et al., 2006; Smith & Bryson, 2007). Whilst imitation research is on the rise and new findings are being published in gesture performance across a variety of experimental designs, few studies have focused on gesture *production* in ASD. Moreover, there is a lack of understanding regarding modality-specific effects on production tasks in developmental disorders (Zoia et al., 2004), in particular, in individuals with autism (Bartak et al., 1975).

Gesture production deficits in individuals with autism have already been published (Dewey et al., 2007; Mostofsky et al., 2006; Rogers et al., 1996; Seal & Bonvillian, 1997; Smith & Bryson, 2007). Deficits in pantomime production in verbal modality (Dewey et al., 2007; Mostofsky et al., 2006; Rogers et al., 1996); visual modality (Smith & Bryson, 2007); intransitive gestures to verbal command (Mostofsky et al., 2006; Smith & Bryson, 2007); and visual cue (Smith & Bryson, 2007) have recently been reported. The identification of gesture production impairments *and* imitation deficits has prompted researchers to consider new theories to explain the gestural deficits in ASD (Dewey et al., 2007; Mostofsky et al., 2006; Smith & Bryson, 2007). If the gestural deficit extends to production, theories addressing only the imitation deficit do not provide a sufficient explanation to account for all of the reported gestural disturbances in autism. Indeed, Smith & Bryson (2007) stressed

that the hypotheses related to imitation in autism have not been definitely supported, and suggested taking a different approach to gesture research; namely, placing autism within current frameworks of dyspraxia using neuropsychological models to inform gesture production in autism.

Selective impairments in gesture performance in adults have been identified. Limb apraxic patients have shown selective deficits in performing transitive gestures (Fukutake, 2003; Heath, Almeida, Roy, Black & Westwood, 2003; Motomura & Yamadori, 1994) and pantomimes (Bartolo et al., 2003; Buxbaum et al., 2005), providing additional evidence that apraxia expression may vary based on gesture category (Heath et al., 2003). Further, modality specific deficits in patients with apraxia have also been documented. Rothi et al. (1986) identified two patients who could not reproduce visually presented gestures but could perform gestures to command without difficulty.

Although only a limited number of studies have tested gesture production in individuals with autism, so far the findings are compelling and the evidence is mounting for a dyspraxic disturbance in ASD (Dewey et al., 2007; Mostofsky et al., 2006; Smith & Bryson, 2007). Moreover, new reports have suggested that praxis impairments cannot be fully explained by motor deficits alone (Dewey et al., 2007; Mostofsky et al., 2006; Smith & Bryson, 2007) leading to the exploration of additional theories to address the gestural deficits. This current experiment tested meaningful gesture production in ASD following previous studies of limb apraxia in adults (Bartolo, 2002; Bartolo et al., 2008; Cubelli et al., 2000). In neurological patient populations, production tasks have been used to evaluate performance of different gesture categories. Observing patterns of performance in individuals with autism may provide behavioural evidence informing the underlying cognitive processes involved in gesture production across gesture categories.

To date, there have not been any published studies in autism comparing transitive gestures, intransitive gestures, and pantomimes in *all* testable modalities. Moreover, this is the only study to date that has tested twenty trials of each gesture

category in each modality. This current research explored production performance across three tasks of meaningful gestures (transitive gestures, intransitive gestures, and pantomimes) and multiple modalities (verbal, visual, and tactile). It also evaluated possible underlying cognitive mechanisms and their impact on performance including visual perception (VP), visual motor integration (VMI), IQ, and tests of working memory [digit recall (DR), word list matching (WLM), and listening recall (LR)].

The aims of the study were, 1) Determine if an ASD group differs from a group of typically developing controls in their ability to produce meaningful gestures, 2) Determine if deficits in gesture production are task dependent (transitive, intransitive, pantomimes), 3) Determine if group differences in gesture production are better accounted for by underlying cognitive deficits in visual motor (VMI), visual perceptual (VP), and working memory abilities (listening recall, (LR) digit recall (DR) and word list matching (WLM), 4) identify the specific error patterns that distinguish the ASD group from their typically developing peers.

6.1.2 Method Review

Nine experimental tasks evaluated the ability to produce gestures on command and on imitation. One production task evaluated the actual use of objects (transitive gestures) and three tasks assessed pantomimes in different modalities including verbal (“show me how you would use a _____”), visual (“show me how you would use this object”), and tactile modalities (“close your eyes and show me how you would use this object”). Two production tasks which tested intransitive gestures were tested in verbal and visual modalities. In the verbal modality, the participant listened to a social scenario and was asked to produce the gesture that would best apply to a given situation (e.g., a football player just made the winning touchdown). In the visual modality, the participant viewed video clips of actors acting out social scenarios, and he or she was asked to produce the gesture that would best fit the situation (e.g., clapping after an actor gives a bow). In the

imitation modality the participants imitated transitive gestures (object use), pantomimes, and intransitive gestures.

For each item, each participant was given a score of 1 in case of success, and 0 in case of failure, thus the maximum score in each task was 20 (18 for production of transitive gestures). Errors were qualitatively classified according to a coding system which measured hand, arm, amplitude, and timing errors.

6.1.3 Results of Meaningful Gestures

Approach to Analysis

The analyses of the production of transitive gestures, intransitive gestures, and pantomimes were performed in five consecutive steps: 1) evaluating group differences in task performance, 2) comparing task performance across gesture types and modalities in both groups, 3) predicting the underlying cognitive mechanisms necessary for intransitive gestures and pantomimes, 4) assessing error types and 5) testing for interactions and exploring correlations and relationships between the production tasks.

Hand Choice

Paired sample t-tests were performed for each production to determine if any differences in the two attempts could be attributed to practice. There were no effects on the production of pantomimes in verbal modality [ASD $t_{18} = 1.71$, $p = .10$; TD paired t-test could not be calculated for the other modalities because the standard error and the mean differences were 0]; visual [ASD $t_{18} = 1.00$, $p = .33$; TD $t_{22} = -1.00$, $p = .33$]; or tactile modalities in either group [ASD $t_{18} = 2.11$, $p = .05$; TD $t_{22} = 1.00$, $p = .33$]. Similarly, no practice effects were identified in intransitive gesture production in verbal [ASD $t_{18} = 1.00$, $p = .331$; TD $t_{22} = -.44$, $p = .66$], or visual modalities [ASD $t_{18} = .000$, $p = 1.00$; TD paired sample t-test

could not be calculated because the standard error and the mean differences were 0]. As a result, all first and second attempts were collapsed across gesture type and modality for the remainder of the analyses.

Group Differences

Welch's independent t-tests were used to determine group differences in the performance of the production tasks for all three gesture types. Welch's t-tests were selected over Mann-Whitney U tests as the analysis of choice to account for the unequal variances in the tested samples. Results of the production tasks showed significant between-group differences, revealing poorer performance of the autistic participants in all modalities of *intransitive* gestures [verbal modality $t_{21.7} = -8.77$, $p < .001$ Cohen's $d = -2.8$; visual modality $t_{23.5} = -7.88$, $p < .001$ Cohen's $d = -2.53$; and imitation $t_{19.8} = -7.40$, $p < .001$ Cohen's $d = -1.29$]. Similarly, the TD group outperformed the ASD group in all tasks of *pantomimes* [verbal modality $t_{20} = -4.81$, $p < .001$ Cohen's $d = -1.57$; visual modality $t_{18.5} = -4.74$, $p < .001$, Cohen's $d = -1.54$; tactile modality $t_{21.8} = -5.75$, $p < .001$, Cohen's $d = -1.83$], and imitation [$t_{21.2} = -7.88$, $p < .001$, Cohen's $d = -2.5$]. See Table 6.1 for detailed descriptives for tasks of imitation and production.

Table 6.1
Results Achieved for the Production and Imitation Tasks by the Autism Spectrum Disorder (ASD) and Typically Developing (TD) Groups.

	ASD (N = 19)	TD (N = 23)	Test Statistic
Spontaneous Object Use	16.5 ± 2.3	18.0 ± 0.2	$t_{18.2} = -2.7$, $p = 0.014$
Object Imitation	12.4 ± 4.5	19.2 ± 0.8	$t_{18.9} = -6.5$, $p < 0.001$
Intransitive Gestures Verbal	9.1 ± 3.8	17.2 ± 1.3	$t_{21.7} = -8.8$, $p < 0.001$
Intransitive Gestures Visual	9.6 ± 4.2	17.8 ± 1.8	$t_{23.5} = -7.9$, $p < 0.001$
Intransitive Gestures Imitation	13.1 ± 3.7	19.5 ± 0.9	$t_{19.8} = -7.4$, $p < 0.001$
Pantomime Verbal	13.8 ± 4.5	19.0 ± 1.2	$t_{20} = -4.8$, $p < 0.001$
Pantomime Visual	12.4 ± 6.1	19.1 ± 0.8	$t_{18.5} = -4.7$, $p < 0.001$
Pantomime Tactile	10.9 ± 5.3	18.2 ± 1.9	$t_{21.8} = -5.8$, $p < 0.001$
Pantomime Imitation	9.3 ± 5.0	18.8 ± 1.7	$t_{21.2} = -7.9$, $p < 0.001$

Note. Mean ± SD. Test used: Welch's t test.

Predicting Group

In the *meaningless* gesture experiment, the first analysis established which variables best accounted for group differences using a stepwise logistic regression model to predict group membership. However, in the *meaningful* gesture experiments, this analysis was not conducted due to the multicollinearity of the variables. See Fig. 5.3 for the scatterplot matrix and results of Pearson correlations for imitation and production of meaningful gestures. A scatterplot matrix was made of the log-odds of success of the various tasks. The upper panels show the scatterplot, whilst the lower ones provide the Pearson correlations. Except for spontaneous object use, all of the measures were highly correlated, especially the different modalities within the same task. The size of the font is proportional to the correlation. So a correlation that is twice as strong has twice as large of a font. The separation between the ASD and TD groups was also striking.

Task Performance Across Gesture Modalities

Intransitive Gestures

A logistic (binomial) regression model was fitted to determine whether there was an effect of autism and/or an effect of modality in the production performance of intransitive gestures in the ASD and control groups. Using the log odds of success (OR), the results revealed that there was a large group difference in intransitive gesture production; the TD children performed the tasks 9.48 fold better than the autistic participants. In particular, imitation had a *higher* success rate than the verbal [OR =.35] and visual modalities [OR =.42] (see Table 6.2). Lastly, to compare the verbal and visual modalities to each other, a linear hypothesis function was used and the results were not significant ($F < 1$). In sum, there were significant differences between performance in imitation modality and verbal modality and imitation modality and visual modality, although verbal and visual modalities did not statistically differ from one another. See Table 6.2 for the odds of success of intransitive gesture production.

Table 6.2
Results of Performance of Intransitive Gestures Across Modalities

	Modality	Odds Ratios	p-value
Group	Verbal	.35	<.001
	Visual	.42	<.001
	Imitation	1.00	reference
	ASD	1.00	reference
	TD	9.5	<.001

Pantomimes

Building the same simple model used for intransitive gestures, pantomime production was evaluated including the factors of group, modality, and an interaction term for group and modality. A large group difference was revealed [OR =11.5] along with significant differences in modality performance. Pantomime imitation had the *lowest* success rate, followed by the tactile [OR=1.1], visual [OR=1.7], and verbal modalities [OR=2.2]. Moreover, the differences between visual and imitation and verbal and imitation modalities were statistically significantly different from each other. See Table 6.3 for the model summary. The model was followed by linear hypothesis tests to determine if differences in task performance were evident between verbal and visual; visual and tactile; and verbal and tactile modalities in pantomime production. The verbal and tactile modalities were also statistically significant from each other [F (1, 164) = 6.67, p = .01].

Table 6.3
Results of Pantomimes across Modalities

	Modality	Odds Ratios	p-values
	Verbal	2.17	.003
	Visual	1.72	.03
	Tactile	1.12	.61
	Imitation	1.00	reference
Group	ASD	1.00	reference
	TD	11.5	<.001

Transitive Gestures

Following the same steps as the previous analyses, a simple model was used to test for an interaction, including the factors of group, modality, and an interaction term for group and modality. The model was run again as an additive to compare spontaneous transitive object use with transitive gesture imitation using imitation as the reference (i.e., use – imitation). A large group difference [OR =16.42], along with a significant difference in performance between imitation and spontaneous use modalities [OR=7.33] was identified. Spontaneous object use was significantly easier to perform for both groups than transitive gesture imitation. See Table 6.4 and Fig. 6.1 for the model summary. Fig. 6.1 plots the probabilities of success in meaningful gesture imitation and is spaced on a log scale. The lines represent the group means across tasks.

Table 6.4
Production of Transitive Gestures

	Modality	Odds Ratios	p-value
	Object Use	7.33	.003
	Imitation	1.00	reference
Group	ASD	1.00	reference
	TD	16.42	<.001

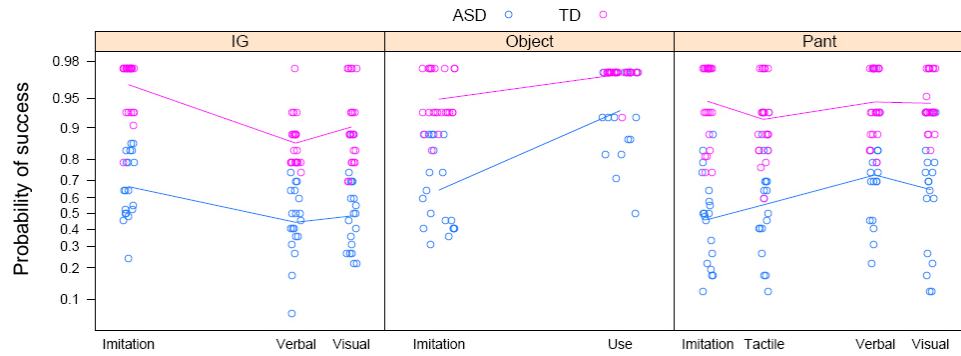


Figure 6.1. Probability of success in tasks of meaningful gesture imitation in the ASD and TD groups.

The final logistic regression model began with a simple model including group, task modality, and group and task modality. No interaction was identified [$F_{8,360} = 1.14, p = .35$] and the covariates were added to the model without the group and task modality interaction code. In addition to the covariates, two new interaction terms were created: one testing an interaction between cognitive variable (covariate) and *task* and the other testing the interaction between cognitive variable and *group*. The results from the final model, in which all main effects and the significant interactions were included, are provided in Table 6.5; higher odds ratios are indicative of higher odds of success. The analyses used intransitive gesture in the imitation modality as the reference to compare the tasks to one another. The odds of successful gesture performance among typically

developing children were 9.34 fold higher than among autistic children.

Intransitive gesture imitation did not significantly differ from either pantomime production in the verbal modality [$p=.772$] or pantomime production in the visual modality [$p = .484$]. The gesture categories and modalities that did significantly differ from the reference, intransitive gesture imitation, are shown in Table 6.5.

Spontaneous object use was the most successful production type followed by pantomimes in the tactile modality, pantomime imitation, intransitive gestures in the visual modality, and finally, intransitive gestures in the verbal modality, which was the most difficult task for both groups.

Higher VP and listening recall were associated with higher odds of success [OR = 1.06 and OR=1.02 respectively]. Higher DR was associated with a lower success rate, while higher FSIQ was associated with lower success rate among TD children, but it was not predictive for autistic children. Table 6.5 shows the effect of the cognitive variables on the success rate.

Table 6.5
Final Model Including all Task Modality Interactions

Final Model		OR	p-value
Task Modality	IGVerbal	.331	<.001
	IGVisual	.414	<.001
	IG Imitation	1.00	reference
	PantVerbal	1.06	.772
	PantVisual	.856	.484
	PantTactile	.516	.002
	PantImitation	.461	<.001
	Transitive Use	7.11	<.001
	Transitive Imitation	.814	.333
Group	ASD	1.00	reference
	TD	9.34	<.001
Cognitive Variables			
LR		1.02	<.001
DR		0.98	.046
VP		1.06	.002
FSIQ	within ASD	1.00	reference
	within TD	0.98	.020

Error Pattern Analyses for Production and Imitation Tasks

To investigate the errors contributing to the meaningful gesture production performance, the percent of gestures with specific error types among all gestures with errors, were calculated. Binomial regression models were used to compare the error rates between the two groups. The following codes were used across all three tasks: hand posture, arm/trajectory, amplitude, timing, and reversal errors. The pantomime errors also included body-part-as-object and distance errors. For intransitive gesture coding, an error code was included that accounted for the participants providing a verbal response to the stimuli without providing a gestural production.

Significant differences were revealed between the two groups in error rates in pantomimes in verbal, visual, and tactile modalities suggesting that the probability of making a particular error type was not only task dependent but also *modality* dependent. Pantomime production in verbal modality revealed a main effect of *arm* errors [$F_{1,29} = 20.1$, $p < .001$]; in visual modality, *hand* errors were statistically significantly different between groups [$F_{1,33} = 10.8$, $p = .002$] and in the tactile modality there were between group main effects of *hand and arm errors*, [$F_{1,34} = 21.7$, $p < .001$; $F_{1,34} = 19.1$, $p < .001$]. However, main effects in the opposite direction were also identified (typically developing group with higher error rates when the participants without errors were not included in the analyses [distance errors in pantomime production in verbal modality $F_{1,29} = 4.6$, $p = .04$; body-part-as-object errors in pantomime production in visual modality $F_{1,33} = 14.2$, $p < .001$ and in tactile modality [$F_{1,34} = 5.8$, $p = .02$].

Pantomimes in the tactile modality were performed more poorly than either visual and verbal modalities in both groups, but the ASD group performed this task well below that of the typically developing group

In intransitive gesture production, significant differences in error rates also varied across modalities, in the verbal modality, *hand*, *arm*, and *amplitude*, errors

successfully distinguished groups [$F_{1,39} = 15.1, p < .001$; $F_{1,39} = 13.9, p < .001$; $F_{1,39} = 4.5, p = .04$] whilst errors of intransitive gestures in *visual* modality showed a different pattern. In the visual modality *hand*, *arm*, and *visual response* showed main effects [$F_{1,35} = 5.3, p = .03$; $F_{1,35} = .022, p = .02$; and $F_{1,35} = 21.9, p < .001$]. The ASD group demonstrated an unusual pattern of providing a verbal response to a social scenario without generating a gesture. This error differed significantly from the typically developing group. Not all participants in the TD group made errors and only trials with errors could be used for analyses; therefore, low power may have been a factor as to why additional errors were not statistically different between the two groups.

Correlations and Relationships

Correlations and relationships similar to those explored in Chapter 5 were not performed because the associations among modalities and across tasks were inherent in the logistic regression models that were fitted.

Age as a Predictor of Production Success

A follow-up logistic regression model was fitted that included age as a cognitive variable. The results revealed that age did have a small but significant effect [$OR=1.08, p = .009$], and that as age increased, performance increased for both groups. However, age alone could not explain the dramatic difference between the imitative performances of individuals with ASD and typically developing children. The odds of successful imitation amongst typically developing children remained over 9.3 fold higher than amongst autistic children ($p < .001$).

In this chapter, correlations and relationships were explored within the context of the models of logistic regression and therefore separate correlations were not necessary to perform.

The Effect of ADOS and SCQ in the ASD Group

To explore the effect of ADOS and SCQ performance on gesture production success, two separate models were used to test for an interaction between ADOS, and task/modality and SCQ and task/modality. Since no interaction was found, an additive model measuring the effect of ADOS and SCQ on gesture production in each modality was fitted. The results indicated that lower ADOS scores (fewer autistic characteristics) were associated with higher success but the effect of SCQ did not reach statistical significance [$p = .087$]. See Table 6.6 and Fig. 6.2 for results of the effects of ADOS and SCQ on production.

Table 6.6
ADOS and SCQ Effects on Production

Final Model		OR	p-value
Modality	IGVerbal	.435	.007
	IGVisual	.484	.018
	PantImitation	.453	.010
	Object Use	6.19	< .001
	IG Imitation	1.00	reference
	ADOS	.919	< .001

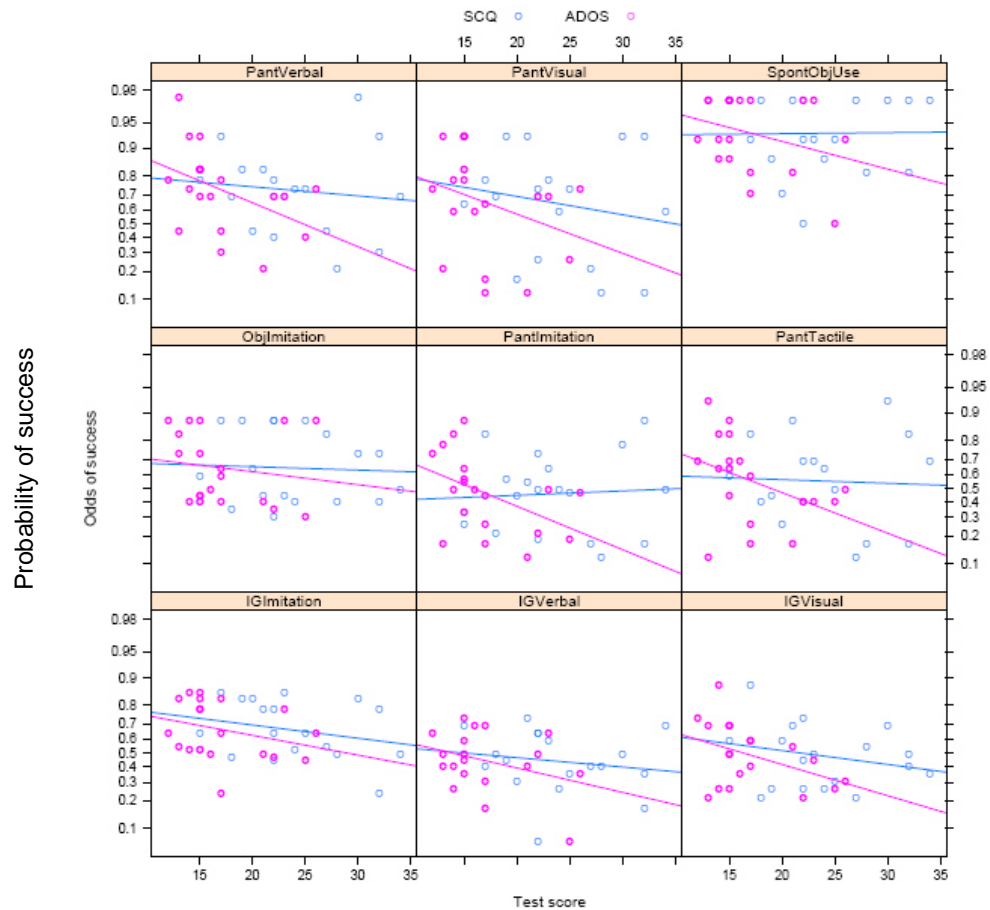


Figure 6.2. The effect of ADOS and SCQ performance of gesture production in the ASD group.

6.1.4 Discussion

In summary, the individuals with ASD performed all tasks more poorly than a group of typically developing peers, and their production performance could not be fully explained by the cognitive measures included in the model. This is the first report of significantly different performance across three separate tasks of production and modalities revealed after logistic regression analysis. Other studies have often collapsed intransitive and pantomime imitation scores together for analysis and/or not included a test of transitive gestures. This section will summarise the production results and then discuss the intransitive gesture and pantomime production results.

The results of this study support previous findings suggesting that gestural processing deficits in individuals with autism are not limited to imitation alone, but extend to gesture *production*. The individuals with autism demonstrated impairments in the production of meaningful gestures including both intransitive gestures and pantomimes. Moreover, gesture production deficits in both intransitive gestures and pantomimes were revealed in all tested modalities.

When comparing the production results to the imitation results, intransitive gesture imitation was performed better than intransitive gesture production in verbal and visual modalities (verbal and visual modalities did not differ from each other). No group and task interactions were identified in any of the production analyses, suggesting that the effect of autism was the same across tasks. The individuals with autism performed *all* tasks much more poorly than the participants in the typically developing control group. Pantomime imitation had the lowest rate of success, followed by the tactile, visual, and verbal modalities. Results of the pantomime in verbal and visual and visual and tactile modalities did not significantly differ from one another. Interestingly, this same overall pattern of production for intransitive gestures and pantomime performance across modalities was observed in the TD group, suggesting that even in typically developing populations, the performance of production tasks may vary depending on the tested gesture type and modality. It is worth noting that *opposite* patterns emerged in intransitive gesture versus pantomime production for both groups. In intransitive gesture production, performance was *improved* by the observation of a model; therefore the gesture performance in imitation modality was superior to that of verbal and visual modalities. In contrast, the observation of a model did not improve pantomime production; in fact pantomime imitation was the most difficult modality followed by tactile, visual, and verbal modalities. These findings suggest that intransitive gestures and pantomimes may rely on different neurointegrative mechanisms to perform.

The finding that as a group, the individuals with autism performed much more

poorly than the typically developing control group on all tasks, but performed in a similar overall pattern, is intriguing. Indeed, group and task interactions were not identified, and similar cognitive processes were recruited in both groups. In an attempt to reconcile these differences in task performance, key underlying cognitive mechanisms as well as error patterns that may have affected production performance were investigated.

The ASD and TD groups were matched for chronological age, Verbal Intelligence, Performance Intelligence, and Full Scale Intelligence. In addition to the tests used in group matching, preassessment cognitive measures were also administered and included tests of visual perception, working memory, and visual-motor integration. Results of the cognitive tests revealed that in measures of visual motor integration (VMI), and two tests of working memory (word list matching and listening recall) the ASD group performed significantly more poorly than the TD controls. Group differences were not identified in tasks of visual perception (VP) or digit recall (DR). All preassessment and group matching measures were included in the production analyses to determine if group differences remained after the cognitive variables were statistically controlled. The same cognitive variables predicting imitative success of meaningful gestures also predicted production success (see results of meaningful gestures, Chapter 5, Section 5.2.3 and Section 5.2.4 for a discussion of counterintuitive findings).

In both intransitive and pantomime gestures, an increase in listening recall and visual perception was associated with greater success. This association extended across modalities in both gesture categories. Higher performance on the cognitive measures, specifically listening recall and visual perception were associated with better production performance but could not fully account for the impaired gestural performance identified in the ASD group. Listening recall and visual perception will be highlighted in turn under the respective gesture category (intransitive gestures and pantomimes) discussion.

Following the analyses of the cognitive variables, error type analyses were

conducted. In intransitive gesture production, significant differences in error rates differed across modalities. In the verbal modality, *hand*, *arm*, and *amplitude* errors successfully distinguished groups whilst error rates of intransitive gestures in the *visual* modality showed main effects of *hand*, *arm*, and *verbal response only*. Errors of internal configuration (e.g., hand errors) and spatiotemporal error patterns (i.e., arm and amplitude errors) are often identified in patients with limb apraxia (Bartolo et al., 2008; Buxbaum et al., 2005) and developmental dyspraxia (Mostofsky et al., 2006).

Hand errors are considered errors of internal configuration whilst arm and amplitude errors may be considered as spatiotemporal error patterns. An interesting error pattern was revealed in the ASD group that has not been described before in the literature. In particular, the individuals with autism provided a verbal response only to a social scenario without generating a gesture. This error, 'verbal response only', is a unique type of error that was evidenced only in the ASD group.

Significant differences were revealed between the two groups in error rates in pantomimes in verbal, visual, and tactile modalities. Pantomime production in verbal modality revealed a main effect of *arm* error rates, in the visual modality, *hand* error rates distinguished groups, and in the tactile modality there were between group main effects of *hand and arm errors*. Similarly to intransitive gesture production, between group differences in error rates of internal configuration and spatiotemporal error patterns were revealed. However, in the pantomime production tasks, main effects of error rates in the *opposite* direction were also identified (the typically developing group showing higher error rates). These error rates included distance errors in pantomime production in verbal modality and body-part-as-object errors in visual and tactile modalities. It has been suggested that body-part-as-object errors may be a compensatory strategy, allowing a participant to rely on an intact semantic system to produce a gesture (Bartolo et al., 2003). Body-part-as-object errors contain semantic information related to object function, but the hand configuration is not produced correctly

(Bartolo et al., 2003). Subsequently, the presence of this error type would suggest that the lexical route was recruited for production tasks in the typically developing control group.

Intransitive gestures. In the intransitive gesture production tasks, the overall pattern of performance was the same between the two groups, although the gesture production of the individuals with autism was markedly impaired compared to their typically developing peers. These results follow the reported findings of Smith & Bryson (2007), who showed worse intransitive gesture performance in imitation modality than in verbal command modality in both the autism and the typically developing control groups. Importantly, this same pattern of performance was not observed during the production and imitation of pantomimes. Although intransitive gesture error rates consisted of hand configuration and spatiotemporal error patterns, in the visual modality, another error type was observed. An error described as ‘verbal response only’ is a unique error type that has not been described before in either autism or apraxia studies and is one that captures a phenomenon that we suggest is related to social cognition. Unlike pantomimes that test actions with objects, intransitive gestures contain social information and are incorporated into social contexts. Social communication deficits are well-documented in individuals with autism (Kanner, 1943; Wetherby, Prizant, & Schuler, 2000) along with deficits in gestures for social purposes (Wetherby et al. 2000). Indeed, these findings suggest that individuals with autism fail the intransitive gesture tasks for different reasons other than spatiotemporal error patterns; therefore, a different pattern of gesture processing may be expected in intransitive gestures as compared to other gesture types.

These findings provide the foundation for a theoretical explanation as to why the individuals with autism provided a correct verbal response without generating a gestural response that lies in the increasing complexity of gestural processing tasks similarly to the recent reported studies in language processing (D. Williams, personal communication, November 21, 2008). Mason and colleagues (2008)

suggest that as the processing load increases, individuals with autism may not possess the ability to recruit the required additional mechanisms necessary for adequate performance (Mason, Williams, Kana, Minshew, & Just, 2008; Williams & Minshew, 2007). These current findings may prove to be an extension of their theory suggesting that this poor performance of intransitive gesture production (below the performance of the typically developing controls) compared to imitation performance may be a result of an already fragile social communicative processing network; subsequently, when the gestural production tasks require on-line processing necessitating the recruitment of socio-cognitive demands that tax an already overloaded and vulnerable system, this pattern of praxis processing emerges. The increased complexity of the task in this case does not refer to the motoric production of the gesture but rather to the synthesis of the cognitive mechanisms, in particular demands in social cognition that demand simultaneous and instantaneous processing. Interestingly, the *verbal response only* error was only statistically different from the other errors in the visual modality. Visual processing deficits have also been reported in autism and according to these current findings, higher visual perception was associated with higher rates of success. Therefore, one possibility may be that additional cognitive demands proved to be too difficult to process together with the gestural and social cognitive requirements.

Pantomime Production. Following the findings of Rogers and colleagues (1996) and Mostofsky et al. (2006), gestural impairments in individuals with autism were not limited to imitation. These current findings revealed that pantomime *imitation* proved to be the most difficult modality in which to successfully perform pantomimes followed by tactile, visual, and finally, verbal modalities. The overall pattern of production of the ASD group was the same as that of the typically developing participants, but error types successfully distinguished the production failures of the individuals with autism from those of their age-matched peers.

The tasks assessing visual perception and listening recall were associated with higher rates of pantomime production success. On the basis of a single case

study, Bartolo et al. (2003) found that working memory abilities would play a role in producing and imitating pantomimes.

In autism, studies of working memory have provided mixed results (Bennetto, Pennington, & Rogers, 1996; Griffith, Pennington, Wehner, & Rogers, 1999; Williams, Goldstein, & Minshew, 2006). Rogers et al. (1996) did not find a relationship between tests of visual recognition memory and pantomime. Others have identified spatial working memory deficits in individuals with autism (Williams et al., 2005). However, working memory is not a unitary measure but is made up of various components including the phonological loop, central executive, and visuospatial sketchpad (Duff & Logie, 2001; Pickering & Gathercole, 2001). Therefore, it is critical that the different aspects of working memory are tested to determine which area of working memory is impaired in ASD. Few studies in autism have evaluated working memory and its relationship to imitation (Rogers et al., 1996). Although visual working memory was not directly assessed in this study, listening recall is a task that taps into the central executive. It has been suggested that the role of the central executive is to coordinate the performance of multiple tasks (Duff & Logie, 2001). In this study, working memory appears to have played a role in the performance but it is not enough to fully capture the reasons behind the production failures across modalities.

Intransitive gestures have been purported to be less complicated to perform than pantomimes (Mozaz et al, 2002). However, these current results indicate that in verbal and visual modalities, both the ASD and typically developing groups performed pantomimes better than intransitive gestures in the same modalities³. Moreover, the individuals with autism performed pantomimes across modalities significantly more poorly than their typically developing peers. To reconcile these findings of impaired gesture performance in the ASD group, an exploration of gesture production in developmental dyspraxia was considered.

³A version of this finding has been submitted to Cortex. The submitted version can be found in Appendix G.

These current findings differ from the results reported by Zoia and colleagues (2002) describing the hierarchy of gestural performance across modalities (Zoia, Pelamatti, Cuttini, Casotto, & Scabar, 2002). Zoia and colleagues (2002) found that typically developing children demonstrate a maturational pattern beginning with the successful imitation of transitive gestures, followed by visual plus tactile, visual, and finally, verbal modalities and also that children with developmental coordination disorder demonstrate a combination of a delay and a specific deficit in visual plus tactile modality. The authors did not test tactile modality without visual inputs and they did not test autistic participants. The authors suggested that the performance of children with developmental coordination disorder is most likely linked to “a dysfunction in the sensorimotor integration as suggested by Ayres” (Zoia et al., 2002, p. 704).

Ayres was the first who described poor perception of tactile input in children with developmental dyspraxia, and this topic has been studied for over three decades (Ayres, 1965, 1972, 1977 cit. in Cermak, 1985). Specifically, the author described an association between motor planning and difficulties in tactile perception and problems in interpreting sensory motor information including spatial and temporal inputs through the sense of touch were implicated (Cermak, 1985). Moreover, tactile impairments have been identified as an important causal factor in developmental dyspraxia (Ayres, 1972 cit. in Morris, 1997). In line with dual-route models of praxis processing, selective impairments in the tactile modality in limb apraxia patients have already been reported (De Renzi, 1985) suggesting that impairments in the tactile modality in individuals with autism may be indicative of a dyspraxic account of gestural processing.

Visual and verbal impairments in pantomime production were also revealed in this current ASD group. These findings follow previously published reports that individuals with autism demonstrate deficits in pantomime production, including the visual modality (Smith & Bryson, 2007) specifically in producing actions upon verbal request (Rogers et al., 1996; Smith & Bryson, 2007).

Rogers and Pennington (1991) acknowledged that their theory of self-other mapping could not account for all the gestural deficits observed in individuals with autism and they used the phenomenon of echolalia as an example to illustrate their point. Putting forth an intriguing hypothesis, the authors suggested that there would most likely be evidence of dissociations of performance when comparing verbal imitation and body imitation in autistic individuals with echolalia, and suggested that different brain regions and neural circuits may ‘correspond to different representational systems’ in ASD. They subsequently outlined the neural circuitry that may be involved in echolalia and described how that system could bypass meaning.

This prediction is striking and may shed light on praxis processing in ASD, particularly in the performance of meaningful and meaningless gestures production. As discussed in Chapter 5, Cubelli and colleagues modified a neuropsychological model of praxis processing (Rothi et al., 1991). This dual-route model allows for two independent routes of gestural processing; one responsible for the processing of meaningful gestures along the lexical route, and the other for the processing of meaningless gestures along the non-lexical route (Cubelli et al., 2000). Once a gesture is not recognised as familiar, it is processed as though meaningless along the non-lexical route (Bartolo et al., 2001). The non-lexical route may be accessed directly using the visuomotor conversion mechanism, therefore bypassing meaning just as Rogers and Pennington (1991) predicted in the case of echolalia.

The findings that individuals with autism demonstrate impairments in gesture production in multiple modalities also follow previous studies in adult limb apraxia patient populations (Bartolo et al., 2008; Cubelli et al., 2000; Zoia et al., 2002). Different sensory input modalities including verbal, visual (gesture) and visual (object) may be potentially disrupted at critical points along either the lexical or non-lexical route. Patients have been identified with selective impairments in one modality over the other. For example, limb apraxia patients

have been identified who could not imitate pantomimes but could produce pantomimes to verbal command (Ochipa et al., 1994) and others who could imitate intransitive gestures but not perform the same gestures to verbal command (Cubelli et al., 2000). Still others have reported cases of patients with observed deficits in pantomime to visual modality but not in verbal modality (Rothi & Heilman, 1997) and patients have been reported with deficits in pantomime production across all tested modalities (Bartolo et al., 2003).

Prior to the development of cognitive models of praxis processing, these findings were difficult to reconcile. However, important patterns of praxis processing and selective impairments of gesture category and modality were not successfully captured using group analyses. Therefore, the remainder of this thesis will evaluate the individual performance of each autism participant further investigating their unique praxis profile in an attempt to identify specific praxis syndromes and ultimately, inform gestural processing theories in autism.

The cornerstone for empirical investigations into apraxia should include case study and group methods...extending the traditional theoretical and empirical views of apraxia to include these domains will likely advance our knowledge of the disorder and yield insight into the neural subsystems that give rise to specific levels of the motor representation (Harrington & Haaland, 1997, p. 143).

This approach is important in developmental disorders and is useful in providing a foundation for effective treatment planning (Girolametto, Sussman, & Weitzman, 2007; Lord, 2001; Tager-Flusberg, 2004). When working with a heterogeneous population such as autism, it is critical to determine the “peaks and valleys within a child’s own profile” not only at the group level but on an individual basis (Kuschner, Bennetto, & Yost, 2007, p. 795). As a starting point for treatment, the identified strengths can be used to scaffold the weaknesses (Lord, 2001). Only after administration of a complete battery of tasks, can a detailed account of an

individual's strengths and weaknesses be designed thereby lending itself to the development of a unique cognitive profile. Interventions cannot take for granted a "typical sequence of learning" but rather they must be tailored to each individual, paying attention each of the strengths and weaknesses and applied to relevant and functional goals for the child (Lord, 2001).

CHAPTER 7

ANALYSIS OF PRAXIS PROCESSING IN INDIVIDUALS WITH AUTISM

7.1 TESTING A COGNITIVE MODEL OF PRAXIS PROCESSING

7.1.1 Introduction

The approach to analysis in this chapter takes into account individual performance on the battery of tasks, rather than group results. The identification of processing patterns in individuals with autism and the discussion of dissociations in developmental populations, may be misinterpreted if the reason behind the identification of the patterns of performance is not understood. After careful review of the literature, there appears to be some confusion regarding the definition of dissociations in developmental studies as well as the different underlying motivations behind the identification and use of dissociations in the interpretation of results in developmental populations. However, when used appropriately, the identification of dissociations can be a useful tool in interpreting results in paediatric populations.

It is well-known that differences exist between adult and paediatric neurocognitive processing and it is well-known that neuropsychological disorders with similar behavioral performance may arise from different underlying neurological etiologies (Williams, Goldstein, & Minshew, 2006). For this reason, some researchers argue that the application of similar interpretations used in adult patient populations is not appropriate for paediatric cases (Karmiloff-Smith et al., 2003). Most recently, the trend is to focus on the similarities whilst keeping in mind the differences between adult and developmental populations (as discussed in Chapter 5). Following this line, others argue that the identification of dissociations has proven to be a useful tool in the exploration of the underlying cognitive functioning in individuals with autism, necessary for the identification

of patterns of performance (thereby establishing unique cognitive profiles), and in the identification of subgroups of autism (Kuschner, Bennetto, & Yost, 2007; Tager-Flusberg, 1994). Given the heterogeneity of the autism population, the use of dissociations is considered good research practice when incorporated into research that is designed to address specific theoretical questions. .

In this chapter the results achieved by the individual autism participants will be assessed, allowing for evaluation of the different patterns of processing. This approach is an important step forward in developmental dyspraxia studies, which often refer to dyspraxia as a ‘unitary disorder’, thereby failing to capture the level of deficit in gestural processing. Moreover, this analysis extends current research in imitation and dyspraxia in autism, and is the first known multiple single case approach to praxis processing of its kind in ASD.

7.1.2 Method Review

The Apraxia Battery included gestural tasks designed around the components of the cognitive model of praxis processing (Cubelli et al., 2000). Therefore, the tasks included measures for testing each mechanism of the model. Considering the cognitive model modified by Cubelli et al. (2000); tests of recognition, comprehension, and production tested the input lexicon, the action semantic and the output lexicon respectively (see Fig. 7.1). The gestures included object use, intransitive gestures, and pantomimes. The production of gestures was carried out through testing of different modalities. Transitive gestures were assessed by asking participants to demonstrate the actual use of an object. Pantomimes were tested in verbal, visual, and tactile modalities. Instructions included pantomime to verbal command (“show me how would you use *a pen*”), to visual cue (the object is held up for the participant to view and the examiner asks “show me how would you use *this object*”), and to tactile cue (the participant is blindfolded and the examiner gives the participant the object to hold). After the object is recognised, the participant is asked to demonstrate the pantomime of the object while s/he is

still blindfolded).

The non-lexical route was measured by means of two tasks assessing the imitation of meaningless gestures, imitation of hand postures and finger positions.

Based on the components of the cognitive model by Cubelli et al., (2000), five patterns of impairment can be predicted, depending on the level of breakdown in the gestural system:

1. A deficit at the level of the Action Input Lexicon would present as difficulty in recognising seen gestures coupled with an intact ability to execute gestures to verbal command and on imitation (using non-lexical route). Patients will also show difficulties in comprehending seen gestures. In the limb apraxia literature, this pattern is known as *gestural agnosia*.
2. A deficit at the level of the Action Semantic would be characterised by impaired comprehension and execution of meaningful gestures coupled with spared imitation of meaningless gestures. However, given their intact input lexicon, they would be able to disentangle familiar from unfamiliar gestures. This pattern is known as *ideational apraxia of semantic type*.
3. A deficit of the Action Output Lexicon would result in a pattern of praxis processing characterised by a deficit in the production of meaningful gestures but with preserved ability to recognise and attribute meaning to gestures. Meaningless gestures will be imitated given the spared access to the visuo-motor conversion mechanism. This pattern results in an *ideational apraxia of production type*.
4. A deficit at the level of the Visuo-Motor Conversion Mechanism would present as an isolated impairment of imitation of meaningless

gestures but comprehension and production of meaningful gestures would be intact. This would be considered an ideomotor without ideational apraxia (Bartolo et al., 2001). This pattern is called *ideomotor apraxia*.

5. A deficit at the level of the Gestural Buffer would impair all gesture execution whether they were meaningless or meaningful or presented on command or imitation. However, the ability to perform tasks of recognition and comprehension would be spared. This clinical picture would result in both ideational and ideomotor apraxia. This pattern results in two deficits, *ideational and ideomotor apraxia*.

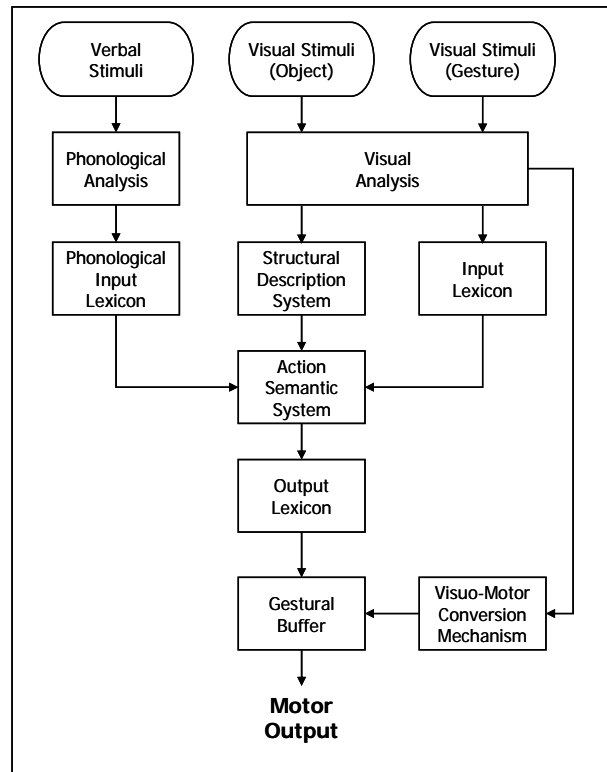


Figure 7.1. Cognitive model of praxis processing (Cubelli et al., 2000).

7.1.3 Results of Individual Cases

Approach to Analysis

In this chapter individual performance was considered. As reported in Chapter 3, all participants were tested using a general neuropsychological battery consisting of IQ measures, tests of visual perception and visual motor integration, and working memory. The stimuli included were easy to perform and indeed, elicited the least errors in the typically developing control group resulting in a quasi-ceiling performance. Since the distribution of results in some tasks were not normal, a cutoff of 2 points below the scores achieved by the worst controls was used to avoid false positive results. Furthermore, the goal of a single case study is to detect a specific cognitive profile, and for this reason it was more important to favour specificity over sensitivity.

Deciding what level of cut-off to use for group comparisons can be challenging. In this study, 2 points below the lowest score of the TD group was used. This approach avoids the cutting-off of any normal scores in the pathologic range. The approach being taken in the current study is the same as that used in adult neuropsychological studies of limb apraxia (Bartolo, 2002; Bartolo et al., 2001; Bartolo et al., 2003). Using this method, SS was the only participant to score below cutoff for Verbal IQ, and EJ was the only ASD participant to score below cutoff for Performance IQ. However, all participants scored above cutoff for the combined IQ score, Full Scale IQ.

In the tests of visual perception and visual motor integration, all participants scored above cutoff in the paper and pencil version of the Beery Test of Visual Perception. CH and EJ scored below cutoff on the Beery Visual Motor Integration, and SS was exactly at the cutoff point. PS scored at the cutoff point for the test of listening recall, but all other participants were above cutoff and all were above cutoff in the test of digit recall. Table 7.1 provides information regarding individual performance on the tasks, and this will be included in the

discussion of praxis performance. The scores with an asterisk indicate that they were performed below cutoff.

Table 7.1
Results of the General Neuropsychological Assessment

	IQ Measures			Visual Spatial Measures		Working Memory		
	VIQ	PIQ	FSIQ	Beery VP	Beery VMI	WLM	Listening Recall	Digit Recall
TD scores								
Range	87-134	69-143	79-139	19-30	78-136	77-143	68-126	71-145
Mean	107.5	112.8	114.4	26.5	102.4	106.0	100.3	107.0
(SD)	(12.9)	(18.8)	(16.5)	(2.5)	(13.4)	(16.2)	(16.8)	(21.6)
Cut-off	85	67	77	17	76	75	66	69
ASD scores								
PS	100	84	90	23	91	96	66	105
BB	88	94	89	27	83	82	85	85
TGA	98	101	100	27	104	92	106	74
JCG	144	134	144	26	97	120	101	96
MK	108	97	103	27	82	94	75	71
JK	126	127	129	27	105	75	77	81
JL	99	117	108	30	88	75	71	137
CH	92	73	81	20	72*	70*	70	100
NM	119	85	101	22	81	114	95	141
EJ	89	72	79	26	73*	89	82	98
AJ	106	89	108	30	84	79	82	92
RN	108	136	124	24	109	104	90	113
NI	138	155	153	30	92	120	100	125
SSA	81*	80	83	25	76	75	75	88
KK	98	91	94	24	82	90	101	85
AR	107	94	100	25	86	99	109	121
IF	87	99	91	27	82	92	85	88
BH	139	115	130	26	93	79	82	92
DS	88	105	90	25	85	100	77	83

Note. Bold and asterisk scores indicate scores below cutoff. Cutoff scores are the worst scores achieved by controls minus two additional points.

Hand Choice

In this chapter there were not any new tasks introduced, subsequently, the hand choice was not a consideration for the single case approach to analysis.

Group Differences

Input Lexicon

Between-group t-tests revealed significant differences in all tests included in the assessment of recognition [transitive gestures $t_{39.9} = -4.77$, $p < .001$, Cohen's $d = -1.54$; intransitive gestures $t_{27.09} = -5.20$, $p < .001$, Cohen's $d = -1.63$; pantomimes $t_{22.68} = -2.53$, $p = .019$, Cohen's $d = -.76$. All three recognition tasks resulted in large effect sizes].

Action Semantic

Between-group differences were evident in all three tasks of comprehension [transitive gesture comprehension $t_{40} = -2.48$, $p = .017$, Cohen's $d = -.80$; intransitive gesture comprehension $t_{22.51} = -4.69$, $p < .001$, $d = -1.56$; pantomime comprehension $t_{24.75} = -5.05$, $p < .001$, $d = -1.61$].

Production

There were significant between-group differences in gesture production, revealing poorer performance of the autism participants in transitive gestures [$t_{18.9} = -6.52$; $p < .001$]; and all modalities of *intransitive* gestures [verbal modality $t_{21.7} = -8.77$, $p < .001$, Cohen's $d = -2.8$; visual modality $t_{23.5} = -7.88$, $p < .001$, Cohen's $d = -2.53$]. Similarly, the TD group outperformed the ASD group in all of tasks of *pantomimes* [verbal modality $t_{20} = -4.81$, $p < .001$, Cohen's $d = -1.57$; visual modality $t_{18.5} = -4.74$, $p < .001$, Cohen's $d = -1.54$; tactile modality $t_{21.8} = -5.75$, $p < .001$, Cohen's $d = -1.83$].

Imitation

Similarly, the TD group outperformed the ASD group in all three tasks of *imitation* [transitive gesture imitation $t_{18.9} = -6.52$, $p < .001$, Cohen's $d = -2.17$; intransitive gestures $t_{19.8} = -7.40$, $p < .001$, Cohen's $d = -1.29$; pantomime imitation $t_{21.2} = -7.89$, $p < .001$, Cohen's $d = -2.5$; again, all large effect sizes].

Meaningless Gestures

Significant between-group differences were revealed in meaningless gestures, with the autism participants performing both tasks of *imitation* more poorly than the TD group [hand imitation $t_{22} = -3.58$, $p = .002$, Cohen's $d = -1.12$; finger imitation $t_{25.5} = -2.95$, $p = .007$, Cohen's $d = -.89$].

Overall, results showed that individuals with autism were impaired in both gesture reception and production. In general, the imitation of meaningful gestures was more affected than the imitation of meaningless gestures. Gesture production was more affected than gesture recognition and comprehension. In Tables 7.2-7.3, data on tasks assessing reception (recognition and comprehension) and production (on command and on imitation) of gestures, are reported.

Predicting Group

This chapter presents individual results and not group analyses, therefore, there are not any analyses to report that predict group.

Table 7.2
Group Results of the TD Controls and Individual Scores of the ASD Participants in the Recognition and Comprehension Tasks.

Participants	Recognition			Comprehension		
	Transitive Gestures	Intransitive Gestures	Panto mimes	Transitive gestures	Intransitive Gestures	Panto mimes
TD scores						
Range	18-20	15-20	15-20	16-20	15-20	16-20
Mean	19.3	17.3	18.1	18.8	18.6	18.9
(SD)	(.81)	(1.3)	(1.4)	(1.2)	(1.6)	(1.0)
Cut-off	16	13	13	14	13	14
ASD						
PS	19	12*	17	18	2*	15
BB	17	14	19	16	13	12*
TG	18	16	20	20	19	19
JC	18	14	18	19	17	15
MK	19	16	18	17	18	17
JK	18	11*	20	18	16	17
JL	19	14	15	18	11*	15
CH	17	10*	13	10*	7*	13*
NM	18	18	11*	18	13	15
EJ	18	12*	9*	17	14	18
AJ	19	14	15	18	16	17
RN	17	16	13	20	13	15
NI	19	15	19	18	16	20
SS	18	16	18	19	12*	17
KK	18	14	17	16	15	15
AR	19	18	17	19	16	19
IF	18	10*	9*	18	14	15
BH	18	13	19	17	16	19
DS	18	15	16	17	17	16

Note. Bold and asterisk scores indicate scores below cutoff. Cutoff scores are the worst scores achieved by controls minus two additional points.

7.2 A SINGLE MULTIPLE-CASE APPROACH TO ANALYSIS

Within the ASD group, AJ scored only one point below cutoff in the imitation of intransitive gesture task, and because this single performance was very close to normal, his gesture profile will not be discussed in detail.

Table 7.3
Group Results of the TD Controls and Individual Scores of the ASD Participants on the Tasks Assessing Gesture Production on Command and on Imitation

	Gestures on Command						Imitation			
	Transitive	Intransitive		Pantomimes			Object	Intran-	Panto-	Mean-
	Object Use	Verbal	Visual	Verbal	Visual	Tactile	Use	sitive	mimes	ingless
ASD scores										
Range	17-18	15-20	14-20	16-20	17-20	12-20	17-20	16-20	15-20	15-20
Mean	17.96	17.22	17.83	19.00	19.11	18.20	19.26	19.54	18.87	17.93
(SD)	(.21)	(1.35)	(1.83)	(1.17)	(.80)	(1.89)	(.81)	(.92)	(1.68)	(1.48)
Cutoff	15	13	12	14	15	10	14	15	13	13
ASD										
PS	18	14	7*	14	12*	14	nd	10*	10*	14
BB	17	7*	6*	15	15	10	18	13*	10*	16
TG	18	15	14	17	19	18	9*	16	11*	18
JC	17	12*	10*	14	16	14	9*	18	13	17
MK	16	5*	5*	15	12*	13	8*	11*	10*	13
JK	16	9*	5*	17	19	9*	18	17	12*	17
JL	15	8*	11*	4*	2*	3*	8*	10*	2*	8*
CH	9*	1*	5*	8*	5*	8*	6*	9*	4*	15
NM	15	3*	8*	6*	2*	3*	8*	5*	3*	8*
EJ	18	8*	4*	9*	4*	2*	17	11*	3*	7*
AJ	17	13	15	16	15	14	18	13*	15	17
RN	18	10*	4*	14	14*	8*	7*	10*	4*	13
NI	18	10*	14	20	19	19	15	17	16	12*
SS	18	7*	10*	19	19	17	15	16	18	15
KK	18	14	12	16	13*	12	12*	13*	5*	18
AR	17	8*	18	19	16	17	18	18	17	17
IF	13*	6*	12	9*	3*	5*	nd	17	9*	14
BH	18	10*	14	17	17	13	8*	11*	7*	19
DS	18	13	9*	14	14*	8*	18	16	10*	16

Note. Nd = no data; *pathological score.

7.2.1 Deficit at the Level of the Input Lexicon

To explain the first pattern, a singular pattern of impairment, Bartolo et al. (2001) found that, when familiar gestures are recognised (at the level of the input lexicon), they are imitated via the lexical route even if the non-lexical route is unimpeded. This hypothesis led to the claim that, on the contrary, if gestures are not recognised, they are considered unfamiliar, and would therefore be successfully processed along the non-lexical route, if this route is spared.

JK, CH, IF, EJ, PS and NM all demonstrated impairments at the level of the input lexicon. Participant JK showed impaired ability to recognise intransitive gestures, coupled with impaired production of intransitive gestures in both verbal and visual modalities. However, he was able to match the same intransitive gesture to a given situation when pictures of social scenarios were presented. This pattern of processing was not predicted by the model by Cubelli et al. (2000). Indeed, according to the model which is a top-down model of praxis processing, a deficit of gesture recognition would be coupled with a deficit in gesture comprehension. To explain this current pattern, it is worth noticing that the recognition and comprehension tasks differ in terms of recall demands. In the recognition tasks, participants were asked to state whether a gesture is familiar or unfamiliar, thereby requiring them to recall previously seen gestures (free recall). The comprehension task, on the other hand, was a forced choice paradigm requiring the participant to choose the correct response given a series of four choices, a recognition recall task.

JK's inability to recall gestures was also evident in his intransitive gesture production performance both in visual and verbal modalities, for which recall of the gesture to be produced was necessary. JK's performance improved when he imitated the same actions, thus when a model was provided. Moreover, JK showed a deficit in the recognition of intransitive gestures, he was below cutoff in

recognising both familiar and unfamiliar gestures. In sum, JK most likely imitated the intransitive gestures along the non-lexical route, which was not impaired given his performance of meaningless gesture imitation. This pattern has been predicted by Bartolo et al. (2001).

Finally, JK demonstrates minor difficulty in retrieving the correct pantomime but this was only evident in the tactile modality (he scored just one point below cutoff in the imitation modality). This inability in producing pantomime is specific of this modality, since in the verbal and visual modality he performed above cutoff. Differently from what is found in limb apraxia patients, JK showed a dissociation between pantomime production (well performed) and intransitive gestures production (impaired) suggesting that these gestures call for different cognitive processes. JK's pattern of praxis processing is most consistent with the pattern of gestural agnosia, but limited to intransitive gestures. This pattern accounts for his inability to recognise intransitive gestures. Further, his ability to comprehend gestures coupled with difficulties in producing intransitive gestures also results in a pattern of ideational apraxia of the procedural type, but again, limited to intransitive gestures. See Fig. 7.2 for level of deficit according to the cognitive model (Cubelli et al., 2000).

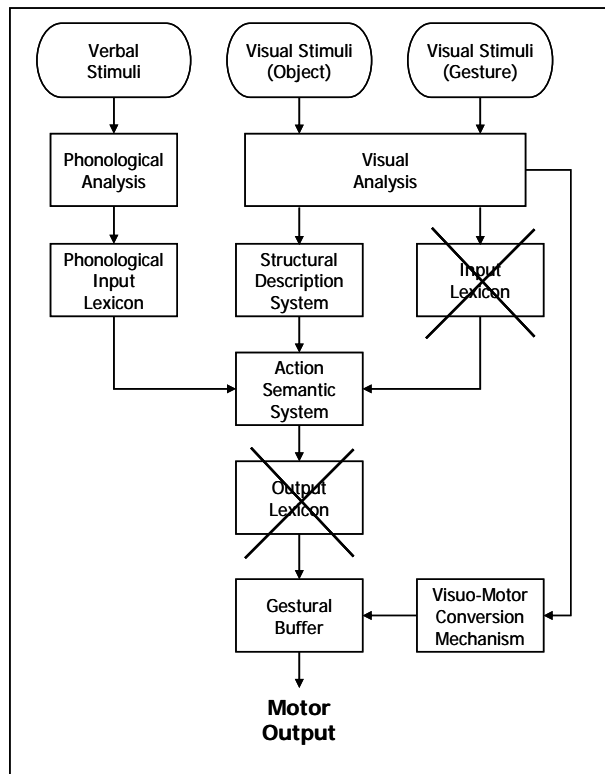


Figure 7.2. Impairment at the level of input lexicon and action output according to the model (Cubelli et al., 2000).

CH also performed below cutoff in the recognition of intransitive gestures and his recognition of pantomimes was at cutoff. CH failed all tasks assessing gesture comprehension across all three gesture categories. As predicted by the cognitive model of praxis processing (Cubelli et al., 2000), CH failed all tasks of meaningful gesture production and imitation secondary to a deficit at the level of the input lexicon and action semantic. See Fig. 7.3 for the level of impairment according to the cognitive model. Given that CH's ability to imitate meaningless gestures was spared, his pattern fits well with gestural agnosia limited to intransitive gestures coupled with an ideational apraxia of semantic type.

IF demonstrated difficulty recognising pantomimes and intransitive gestures. In the production tasks, IF scored below cutoff in all gestures across modalities (intransitive gestures in visual modality was performed at cutoff). IF's pattern is very similar to that of CH, indeed IF also performed above cutoff the imitation of

meaningless gestures, suggesting a spared visuo-motor conversion mechanism. However, IF imitated intransitive gestures above cutoff, and pantomimes below cutoff. Given that IF demonstrated difficulty with gestural recognition, it appears that the lexical route was impaired at the level of the input lexicon. Since IF was not able to determine if a gesture was familiar or unfamiliar, all intransitive gestures were indistinguishable from meaningless gestures; IF perceived intransitive gestures as if they were unfamiliar. Since the non-lexical route was spared (IF performed above cutoff in tasks measuring imitation of meaningless gestures), he successfully processed intransitive gesture imitation using this route. This pattern has been predicted by Bartolo et al. (2001). See Fig. 39 to view the level of deficit according to the cognitive model (Cubelli et al., 2000).

In the case of pantomimes, on the other hand, IF performed pantomime imitation well-below cutoff. The difference in performance between the two gesture categories (intransitive versus pantomimes) may be that IF used the lexical route to imitate pantomimes whilst using the non-lexical route to imitate intransitive gestures. In the assessment, the participants viewed videoclips of actors performing pantomimes and they were told that the actor was pretending to use an object. Therefore, IF most likely attempted to give meaning to the gesture thereby directing him to use the lexical route. Therefore, the use of the non-lexical route appears to be possible for successful intransitive gesture imitation but not for pantomimes.

In summary, IF's pattern is predicted by a deficit at the level of the input lexicon resulting in gestural agnosia limited to intransitive gestures coupled with a deficit at the level of the action semantic for all gestures, accounting for an additional ideational apraxia of the semantic type. See Fig. 7.3 for IF's pattern of praxis processing according to the cognitive model (Cubelli et al., 2000).

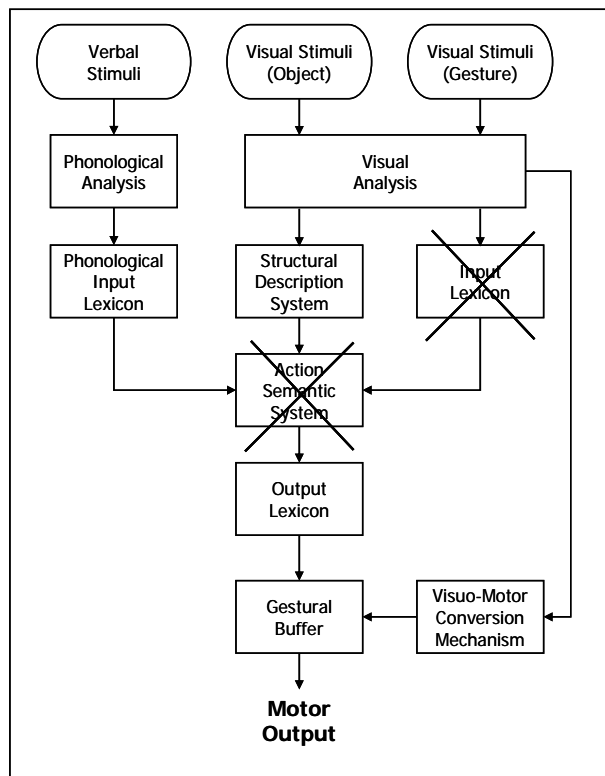


Figure 7.3. Impairment at the levels of the input lexicon and action semantic resulting in gestural agnosia and ideational apraxia of the semantic type according to the model (Cubelli et al., 2000).

EJ presented with a deficit in the recognition of pantomimes and intransitive gestures, coupled with a spared ability to perform a gesture-to-object (or situation) matching task. However, he was able to recognise, comprehend, produce and imitate *transitive* gestures, suggesting that separate processes are required to produce different gesture categories. EJ demonstrated difficulty in the production and imitation of intransitive gestures and pantomimes, which were both performed well below cutoff. He also failed the imitation of meaningless gestures task. According to the cognitive model, this pattern can be explained assuming a deficit at two levels. The first at the level of the input lexicon resulting in a pattern of gestural agnosia, and a second deficit at the level of the gestural buffer, which explains his difficulties in imitating and producing all

gestures. See Fig. 7.4 for the predicted level of impairment for EJ according to the cognitive model (Cubelli et al., 2000).

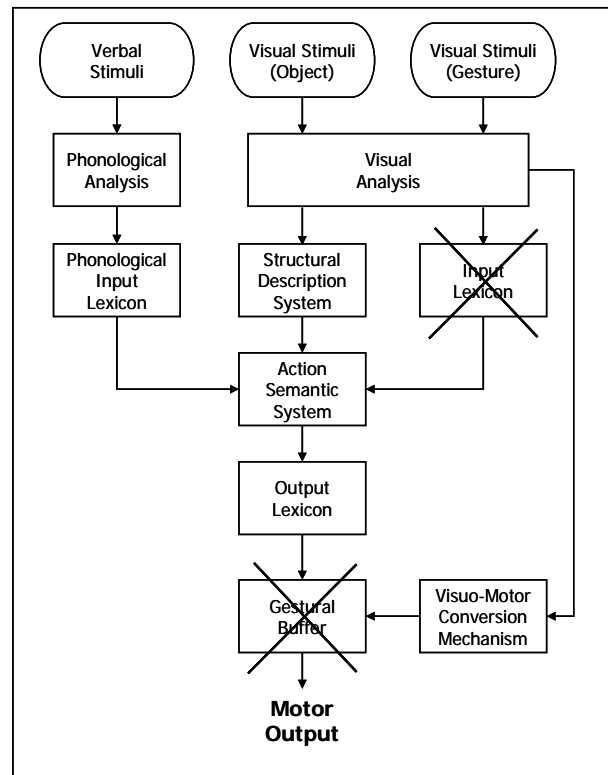


Figure 7.4. Impairment at the levels of two cognitive components; the input lexicon and gestural buffer according to the model (Cubelli et al., 2000).

Although PS was able to recognise, comprehend and produce *transitive* gestures without difficulty, he demonstrated deficits in the recognition and comprehension of *intransitive* gestures coupled with impaired production of all gestures presented in the visual modality (including imitation). This pattern can be explained assuming a deficit at the level of the input lexicon, resulting in gestural agnosia limited to intransitive gestures. PS was unable to produce intransitive gestures because access to the action semantic from the input lexicon was impeded. On the contrary, PS was able to produce intransitive gestures in verbal modality, most likely by accessing the action semantic through the verbal input modality. In PS's

case, even though the non-lexical route was spared, PS was impaired in imitating gestures. One possible explanation is that PS's performance on the imitation of meaningless gestures task was only one point above cutoff, suggesting that the non-lexical route might only be recruited in cases where this route is clearly unaffected. PS performed below cutoff in the production of pantomimes in visual modality, whilst performing in the other modalities without difficulty. This pattern suggests that access to the action semantic is spared from the verbal input, and that the participant experienced difficulty in accessing this mechanism from the input lexicon. It is worth noticing that PS's Verbal IQ scores are higher than his Performance IQ (100 vs 84), suggesting that his verbal abilities are a strength for PS compared to his visual abilities. One possibility is that given PS's difficulty in tests tasking the visual modality, PS presented with imitation deficits of all meaningful gestures and meaningless gestures imitation (he scored just one point above cutoff in meaningless gesture imitation). In summary, PS's level of impairment is at the level of the visual analysis of the stimulus, affecting intransitive gestures, and resulting in gestural agnosia limited to this category of gestures. In addition, impairment in visual analysis also resulted in difficulty in tasks of pantomime production when presented in the visual modality (production and imitation). See Fig. 7.5 for deficit at the level of visual analysis and the input lexicon according to the cognitive model (Cubelli et al., 2000).

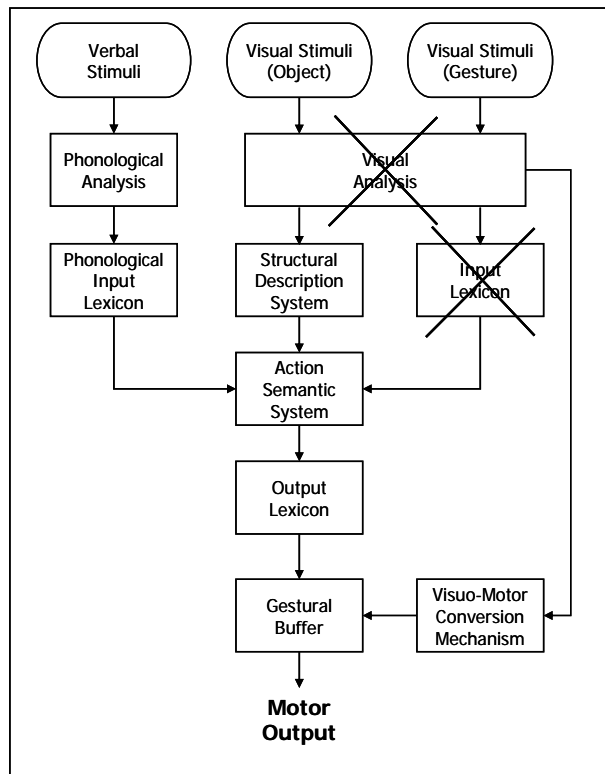


Figure 7.5. Impairment at the levels of input lexicon and visual analysis according to the model (Cubelli et al., 2000).

NM did not demonstrate any difficulty in the performance of recognition or comprehension of either transitive and intransitive gestures. In contrast, NM failed in the pantomime recognition task and he scored just one point above cutoff in the pantomime comprehension task. Apart from a score performed at cutoff in the production of transitive gestures, NM failed all tasks assessing the production and imitation of meaningful and meaningless gestures. This pattern of praxis processing can be explained assuming a deficit at the level of the input lexicon specific to pantomimes, indicative of pantomime agnosia; coupled with a deficit at the level of the gestural buffer, resulting in impaired production and imitation of all gestures. This described pattern presents as ideational with ideomotor apraxia. See Fig. 7.6 for deficits at the level of the input lexicon and gestural buffer according to the cognitive model (Cubelli et al., 2000).

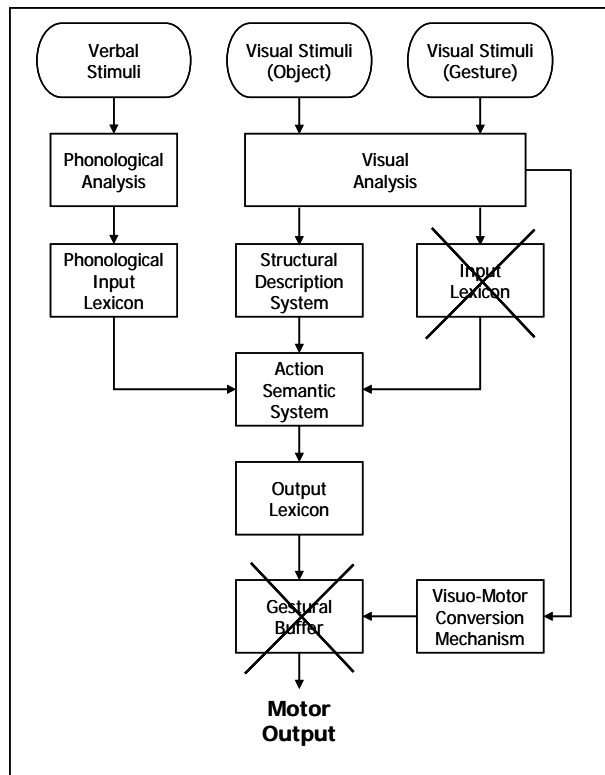


Figure 7.6. Impairment at the levels of input lexicon and gestural buffer according to the model (Cubelli et al., 2000).

7.2.2 Deficit at the Level of the Action Semantic

The second pattern that will now be described results from a deficit at the level of the action semantic. BB performed above cutoff in tasks testing recognition of all gesture categories. He was also able to comprehend transitive and intransitive gestures without difficulty, but he performed below cutoff in the pantomime comprehension task. At the level of production, BB imitated meaningless gestures and produced and imitated transitive gestures and pantomimes above cutoff; however, he failed the imitation of intransitive gestures and pantomime tasks and scored well below cutoff in the production of intransitive gestures. Moreover, his production of pantomimes was performed at cutoff in the visual and tactile

modalities and he performed just one point above cutoff in verbal modality. Overall, this pattern can be explained assuming a deficit at the action semantic limited to pantomimes, and at the output lexicon for intransitive gestures, resulting in ideational apraxia of the semantic type for pantomimes and an ideational apraxia of the procedural type for intransitive gestures. See Fig. 7.7 for the level of impairment according to the cognitive model (Cubelli et al., 2000).

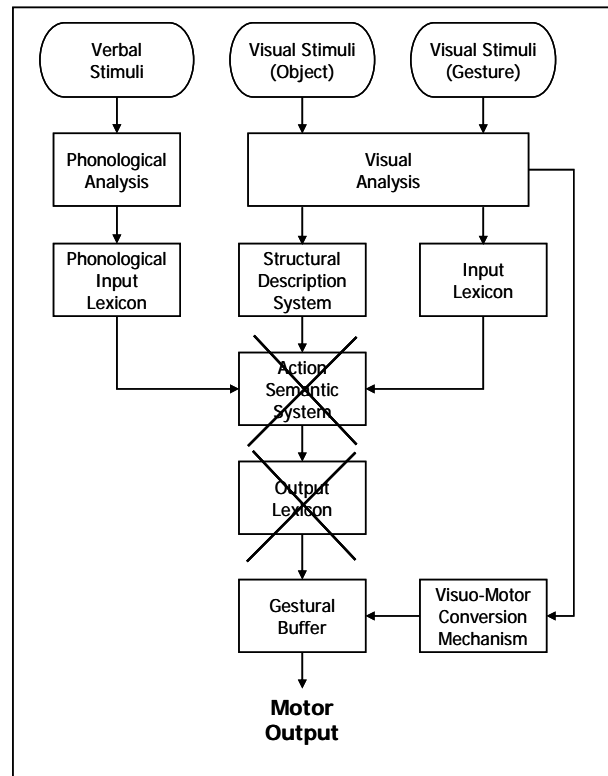
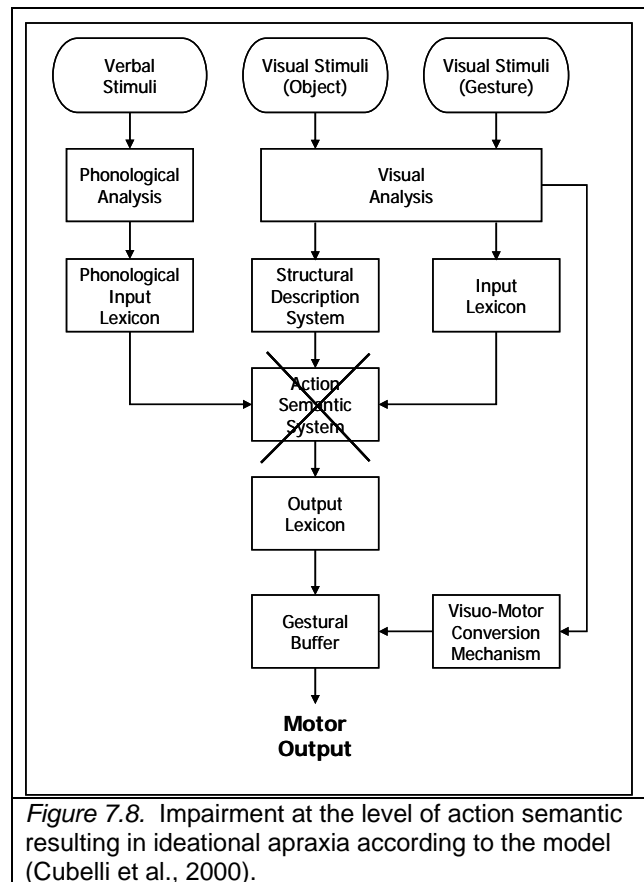


Figure 7.7. Impairment at the levels of action semantic and action output according to the model (Cubelli et al., 2000).

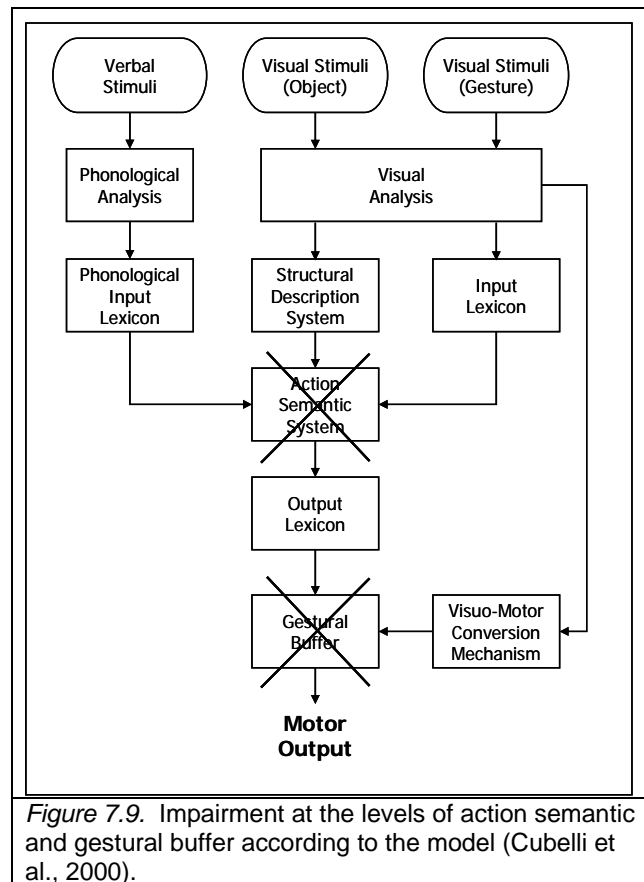
SS was able to recognise, comprehend, produce and imitate both transitive gestures and pantomimes. She showed a selective deficit in the comprehension of intransitive gestures, coupled with an impairment in the production of the same gestures. This pattern is consistent with a deficit at the level of the action semantic resulting in an ideational apraxia of the semantic type, but limited to

intransitive gestures. See Fig. 7.8 for the level of impairment according to the cognitive model (Cubelli et al., 2000).



JL performed above cutoff in tasks assessing recognition of all gesture categories. In tasks of comprehension, JL did not demonstrate any difficulty comprehending transitive gestures or pantomimes, but he failed the task assessing comprehension of intransitive gestures. JL also failed in the production and imitation of all gestures, both meaningful and meaningless (he scored at cutoff in the production of transitive actions), suggesting a deficit at the level of the gestural buffer. In summary, this pattern is most likely characterised as a mixed pattern of ideational apraxia of the semantic type for intransitive gestures, coupled with a deficit at the level of the gestural buffer resulting in an ideational and ideomotor apraxia for the

other gestures. See Fig. 7.9 for JL's pattern of performance according to the cognitive model (Cubelli et al., 2000).



7.2.3 Deficit at the Level of the Action Output Lexicon

The third pattern that will now be detailed results from a deficit at the level of the output lexicon. RN scored above cutoff in all tasks assessing the recognition and comprehension of all gesture categories. At the production level, he was able to produce transitive gestures without difficulty and he scored at cutoff in the imitation of meaningless gestures task. RN scored below cutoff in the production and imitation of *pantomimes* and *intransitive gestures* tasks (at cutoff in pantomimes in verbal modality) suggesting that a deficit at the level of the action

output lexicon affected his gestural production performance. See Fig. 7.10 for an example of the level of deficit of this praxis processing pattern, ideational apraxia of the procedural type according to the cognitive model (Cubelli et al., 2000).

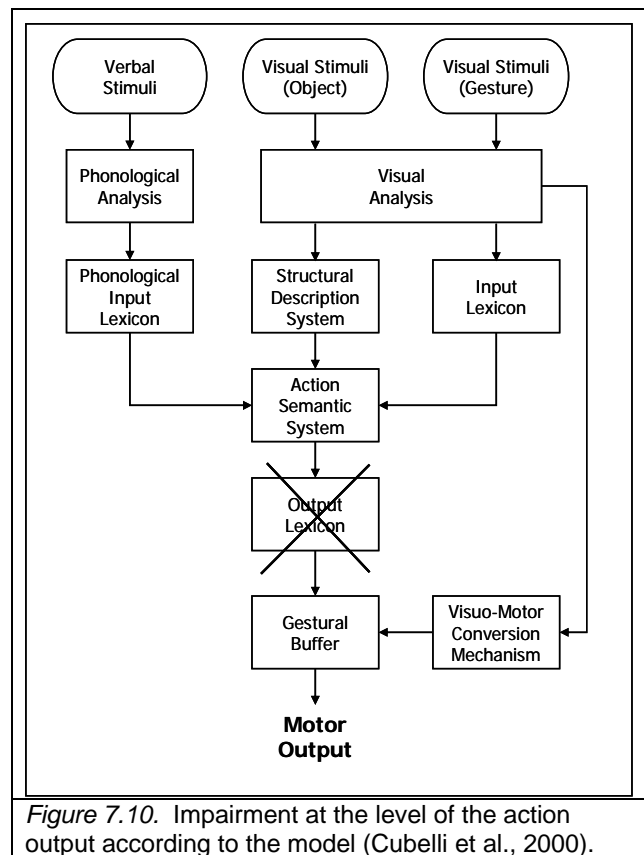


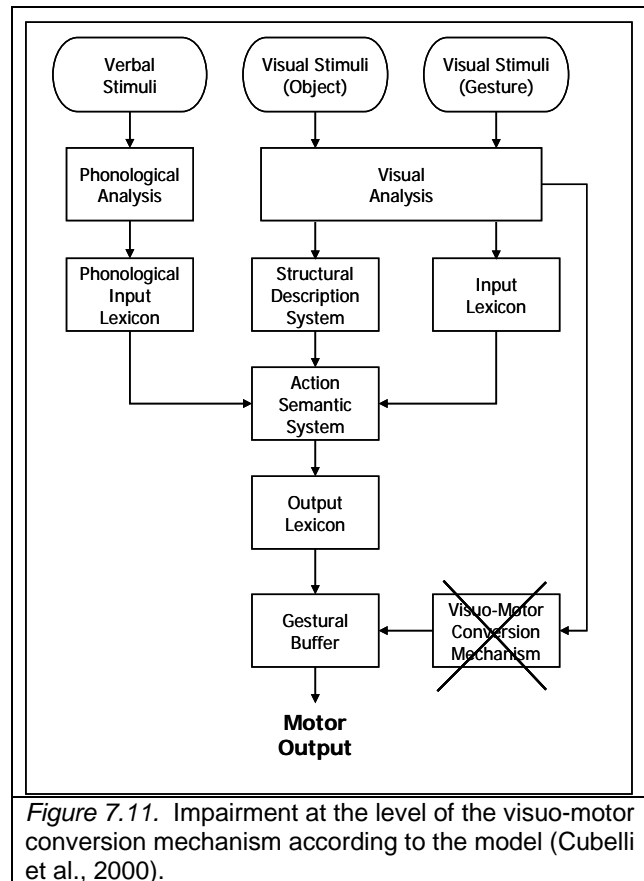
Figure 7.10. Impairment at the level of the action output according to the model (Cubelli et al., 2000).

MK performed all recognition and comprehension tasks above cutoff. He performed at cutoff in the imitation of meaningless gestures. In tasks of gesture imitation and production, MK performed below cutoff in the imitation of meaningful gestures, as well as in the production of intransitive gestures (both visual and verbal modalities). Although his pantomime production was performed above cutoff in the tactile modality, it was below cutoff in the visual modality and one point above cutoff in the verbal modality, suggesting that MK experienced difficulty in pantomime production. As in the case of RN, MK's praxis processing pattern is most likely explained assuming a deficit at the level

of the action output lexicon.

7.2.4 Deficit at the Level of the Visuo-motor Conversion Mechanism

The fourth pattern results in a deficit at the level of the visuo-motor conversion mechanism. NI scored above cutoff in the tasks assessing gesture recognition and comprehension. Apart from one low score in the production of intransitive gestures in verbal modality task, NI produced all meaningful gestures on command and imitation without difficulty. NI demonstrated poor performance in the meaningless gesture imitation task, suggesting that NI's deficit lies at the level of the visuo-motor conversion mechanism. This pattern of praxis processing is indicative of an ideomotor apraxia. See Fig. 7.11 for an example of ideomotor apraxia according to the level of deficit of the cognitive model (Cubelli et al., 2000).



7.2.5 Patterns Not Explained by the Cognitive Model

TG, KK, and BH presented with a deficit in the imitation of meaningful gestures, which were not always associated with a deficit in gesture production. In particular, TG did not fail any tasks assessing gesture production. A deficit in meaningful gesture imitation, with spared ability to produce known gestures and imitate meaningless gestures was not predicted by the cognitive model of praxis processing (Cubelli et al., 2000). This unique pattern suggests that these individuals present with an imitation deficit limited to meaningful gestures. Indeed, imitation deficits are pervasive in autism and this finding may shed light on the underlying social cognitive deficits necessary to perform meaningful gesture imitation, specially, intransitive gestures. Hobson and Hobson (2007)

suggest that deficits in emotional sharing and intersubjectivity affect the development of self-other awareness, and the difficulties in self-other awareness, in turn, affect motor imitation. Therefore, it seems plausible that individuals with autism with known social cognitive deficits would experience difficulty with meaningful gesture imitation. KK and BH performed below cutoff in intransitive gesture imitation, gestures containing social content and so it seems that deficits in social cognition may affect imitation performance, particularly if meaningless gesture imitation is performed without difficulty. Interestingly, all three of the participants, TG, KK, and BH, performed *better* in intransitive gesture imitation compared to their own performance of pantomime imitation suggesting that the interpretation of findings is not that straightforward. Closer inspection of the error types revealed that TG failed the pantomime imitation task secondary to hand, arm, amplitude, and timing errors, errors that are considered spatiotemporal in nature. However, other participants demonstrated impairments in intransitive gesture production without imitation, the opposite pattern.

JC was impaired in his production of intransitive gestures both in verbal and visual modalities, but he was able to imitate these same gestures above cutoff. Closer inspection of the error types revealed that JC did not fail secondary to spatiotemporal error patterns, but rather failed secondary to performing gestures that were not appropriate to the social situation, indicating that he did not understand the social scenario. This presentation of a selective deficit in the production of intransitive gestures seems to be better explained by deficits in social cognition and social communication and is strengthened by the finding that JC's performance of intransitive gesture imitation was aided when the model was provided and he did not have to generate a novel gesture for the social situation. Similarly, AR demonstrated impairments in the intransitive gesture production task in verbal modality, the only task that he performed below cutoff. AR failed the task secondary to providing responses that were not typical of the responses provided by the TD group and saying "I don't know", suggesting that similarly to JC, AR did not understand the social scenario.

Finally, DS performed above cutoff in tasks assessing gesture recognition and comprehension indicating that the input lexicon and the action semantic were not affected. He performed below cutoff in intransitive gesture production in the visual modality and at cutoff in the verbal modality, suggesting that similarly to AR and JC, he experienced difficulty generating the appropriate gesture for the social scenario. Moreover, he was aided by the presence of a model for intransitive gesture imitation (similarly to AR and JC). On the contrary, DS was impaired in pantomime production (verbal modality performed at cutoff) but was not aided by the model as he failed the pantomime imitation task. In some cases, it appears that the presence of a model aids production in individuals with autism (as in AR, JC, and DS for intransitive gesture production) but for others, the performance was not improved upon imitation (KK and BH). Complicating matters further, some participants demonstrated improvement with a visual model for one gesture type but not for other gesture types (DS' performance in intransitive gesture imitation versus pantomime imitation). These cases present with a dissociation in performance between imitation and production of meaningful gestures that present themselves in both directions. These findings are not easily explained by the cognitive model and therefore need to be explored in future studies in individuals with autism.

7.2.6 Discussion

The results of the single case analyses indicate that this approach is a useful tool in predicting patterns of praxis processing in individuals with autism spectrum disorder. Following the challenge for autism researchers to consider individual differences in the interpretation of results (Tager-Flusberg, 2004), and embracing the heterogeneity of the disorder, the single case approach provided specific details that were not captured in group analyses. This type of individual analysis is useful in developmental disorders, specifically in ASD, for a detailed exploration of praxis processing. Commonalities in praxis processing may be one area that could differentiate individuals with autism from one another. Only by

compiling and assessing the gestural profiles of each individual participant did it become clear that patterns of processing were evident.

The battery of tasks was designed around the cognitive components of the model (Cubelli, et al., 2000), and the results indicate that patterns of performance were successfully predicted at each level. Importantly, patterns of praxis processing following adult limb apraxia patients have now been identified in autism for the first time. Praxic syndromes including ideational (of semantic and procedural type); ideomotor; ideational with ideomotor; and gestural agnosia have been uncovered. Moreover, task dissociations that were not captured in group analysis have been revealed. In adult limb apraxia patients, pantomime production has been documented to be selectively impaired, with superior performance of intransitive gesture production (Bartolo, et al., 2003). However, for the first time, cases demonstrating the opposite pattern were identified in the ASD group: impaired intransitive gesture production in verbal and visual modalities with superior performance in pantomime production.⁴

The praxis evaluation was also very detailed in the error analysis and identification of error patterns, and careful attention was given to distinguish between errors that were spatiotemporal in nature versus errors that contained a social communicative component. This was an important step in avoiding misinterpretation of a praxic syndrome that may possibly have been the result of a deficit in social cognition.

Another potential benefit of this approach is the ability to compare reported results of imitation and production in ASD. For example, Smith and Bryson (2007) reported that in their ASD group, pantomimes were performed better in imitation than to verbal command. These results differ from the current group results in showing that pantomime imitation was performed more poorly than production in verbal and visual modalities. However, when considering the praxis profiles, it is

⁴Stieglitz Ham, H., Bartolo, A., Corley, M., Swanson, S., & Rajendran, G (under review) Selective Deficit in the Production of Intransitive Gestures in an Individual with Autism. The submitted article can be found in Appendix G.

evident that a subgroup of individuals performed pantomime imitation similarly to the TD group, and this is similar to Smith and Bryson's (2007) findings. In another example, Smith and Bryson (2007) reported better intransitive gesture performance in imitation modality than in verbal command. The current group results follow these findings, but individual cases demonstrate a pattern of processing which predicts a deficit at the level of the gestural buffer, with deficits in intransitive gesture imitation equally or more impaired than intransitive gestures in production. When the pattern is predicted from the model it provides a more thorough explanation and interpretation of the findings.

Finally, individual analysis is also useful in developmental disorders as a basis for effective treatment planning (Girolametto, Sussman, & Weitzman, 2007; Lord, 2001; Tager-Flusberg, 2004). When working with a heterogeneous population such as autism, it is important to determine the "peaks and valleys within a child's own profile" not only at the group level but on an individual basis (Kuschner, Bennetto, & Yost, 2006, p. 795). As a starting point for treatment, the identified strengths can be used to scaffold the weaknesses (Lord, 2001).

7.3 OVERALL CONCLUSIONS

The main aim of the thesis was to determine if the gestural performance patterns identified in individuals with autism were similar to those in patients with limb apraxia by administering a battery of tasks designed to test cognitive mechanisms built around a neuropsychological model of praxis processing. These tasks assessed both reception and production and evaluated gesture recognition, comprehension, production and imitation across gesture categories and modalities. This battery was administered to determine if the gestural processing impairments in individuals with autism could be more parsimoniously explained by disorders of praxis processing than by the traditional cognitive theories of autism, although an attempt was made to assimilate the cognitive theories of autism into a model of praxis processing.

The results from the battery of tasks in this thesis are most consistent with a dyspraxic account of gestural processing impairments in ASD. This support of this account is based on previous research in patients with limb apraxia and has now been useful in identifying patterns of praxis processing in individuals with autism for the first time. In particular, the results of the battery of tasks have demonstrated that the imitation deficit extends to both meaningful and meaningless gestures in individuals with autism, thereby discounting a symbolic deficit as the core of the imitation deficit in ASD. In meaningful gesture production, deficits were observed across gesture categories and modalities. All of the tested gestures were performed much more poorly in the ASD group than in the typically developing control group, and the deficit could not be attributed to underlying cognitive mechanisms including visual perception, visual motor integration, working memory, intelligence, or age.

The executive function account of autism includes the evaluation of cognitive functions such as attention, working memory, planning, and cognitive flexibility. The working memory tasks that were administered in this study, along with the preassessment cognitive measures could not explain the observed group differences when they were statistically controlled. Therefore, additional testing would be required to determine if the praxis processing impairments in the individuals with autism could be attributed to deficits in cognitive functions typically attributed to a dysfunction in executive functioning.

The neuropsychological battery of cognitive tasks has provided evidence to suggest that performance of gestures can be dissociated from other gesture categories. Patterns of praxis processing were identified in the individuals with autism, including gestural processing patterns similar to patients with limb apraxia including ideational and ideomotor apraxia. These current findings may be considered as an extension of Rogers and Pennington's (1991) prediction of a dissociation between echolalia and body imitation and highlighted echolalia as an example of how imitation can bypass meaning. Indeed, cases of gesture agnosia

have been identified in this group of autism participants. Individual cases were identified who produced meaningful gestures along the non-lexical route, thereby processing the gesture using the visuotransformation mechanism and bypassing meaning as Rogers and Pennington predicted.

In addition to the self-other mapping hypothesis, the mirror neuron theory of imitation has also been considered. Whilst patterns of performance were identified that followed the predictions of the mirror neuron dysfunction account (i.e., an association between pantomime recognition and production), not all of the observed patterns of performance could be reconciled with the theory (i.e., no association between intransitive gesture recognition and production). Further, it appears that successful production of intransitive gestures may require the recruitment of social cognitive skills. Therefore, praxis processing of this gesture category may be impaired secondary to disruptions in functional connectivity of the theory of mind processing network (Mason et al., 2008). Mostofsky et al. (2006) also suggested that disorders of praxis processing may be the result of disruptions in functional connectivity.

The results of this study suggest that different gesture categories may require different cognitive mechanisms to perform; in particular social cognition and social communication may play a role in the production of intransitive gestures whereas selective impairments of meaningless gestures or a deficit in production of a single gesture category may provide evidence for the dual-route models of praxis processing. These findings suggest that the model is useful in predicting patterns of gesture processing in individuals with autism. In conclusion, disentangling imitation and dyspraxia is an important area of research and one that may inform future therapeutic models of gesture and communication intervention in individuals on the autism spectrum.

CHAPTER 8

APRAXIA BATTERY CONCLUSIONS

8.1 APPLICATIONS OF THE CURRENT RESEARCH

8.1.1 Original Contributions of the Research

This current study included two well-matched groups, one typically developing and one group characterised by individuals on the autism spectrum. The groups were matched on five measures including age, Full Scale IQ, Performance IQ, Verbal IQ, and gender, whilst other imitation studies have matched groups but have not matched up to five characteristics. In addition, several standardised cognitive tests were administered and were used in determining if imitation and production performance could be attributed to underlying cognitive mechanisms such as visual perception, visual motor integration, and working memory (including listening recall, digit recall, and word list matching). Moreover, this is the first report including group results as well as a discussion of individual differences in praxis processing in individuals on the autism spectrum. Importantly, these individual differences included specific praxis profiles assessing syndromes of dyspraxia in ASD. Moreover, detailed error codes were designed that considered errors typically observed in patients with apraxia, and also took into account behaviours typically associated with autism.

The meaningless gesture experiment is the first experiment testing specific hand and finger postures based on the research of Goldenberg (1999) in ASD. Although the individuals with autism performed more poorly than their typically developing peers on both tasks of hand and finger imitation, the findings suggest that there may be an association between finger matching (a visual perceptual task) and finger imitation in typically developing children that is not as well established in individuals with autism. Overall, the TD participants were assisted by different cognitive processes

than those in the ASD group, and the cognitive variables were differentially associated with either hand or finger imitation performance in both groups.

The meaningful gestures recognition and imitation experiment was the first experiment to test all three different types of gestures (including object imitation, intransitive gesture imitation, and pantomimes) in tasks of recognition and imitation in individuals on the autism spectrum. Other studies have collapsed intransitive gestures and pantomime imitation scores together during the analyses and interpretation of the results, and/or not included a test of object imitation to compare to gesture imitation. Moreover, twenty items were included for each gesture category in each task; exceeding the number other studies have tested. In the tasks of recognition, intransitive gesture recognition was shown to be the most difficult task, followed by pantomime and object recognition. The opposite pattern emerged in the tasks of imitation; namely, pantomime imitation was performed worse than transitive and intransitive gestures (with intransitive gesture imitation being performed the best). Similarly to limb apraxia patients described by Buxbaum and colleagues (2005) and others described by Rothi and Heilman (1991), an association between pantomime recognition and pantomime imitation was identified. This is the first reported finding of an association between recognition and imitation of pantomimes in ASD. However, these current results do not fully support the MNS hypothesis and an association was not identified between intransitive gesture recognition and imitation. Moreover, these results indicated that individuals with autism not only demonstrated an imitation deficit, but one that also implicated an underlying praxis processing impairment when taking into consideration the error patterns evidenced in the imitation tasks (e.g., internal configuration and spatiotemporal error patterns).

The production section of the apraxia battery tested three different gesture categories across multiple input modalities. The results of this study showed that individuals with autism demonstrate deficits that extend beyond imitation to the processing of gesture production. Intransitive gesture imitation was performed better than production in the verbal or visual modalities. On the other hand,

pantomime imitation had the lowest rate of success followed by the tactile, visual, and verbal modalities. In the tasks of intransitive gestures, the performance was improved by the observation of a model, but this was not the case for pantomimes that showed that imitation was the weakest modality. These findings suggest that pantomimes and intransitive gestures may rely on different underlying cognitive processes. The intercorrelations of these cognitive processes resulting in the selective deficits of gesture types and task dependency is an area currently under exploration in ASD.

In intransitive gesture production, an error pattern was revealed in the ASD group that has not been identified before in the autism or apraxia literature. In particular, the individuals with autism often provided a *correct* verbal response to a social scenario without generating a gesture. This error, coined 'verbal response only', is a unique type of error that was evidenced only in the ASD group (see section 8.1.2 for a discussion of future extensions of the research).

Finally, the individual performance of each autism participant was investigated to identify their unique praxis profile in an attempt to characterise specific praxis syndromes. Importantly, patterns of praxis processing following adult limb apraxia patients have now been identified in autism for the first time. Ideational, ideomotor, mixed apraxia, and gestural agnosia have been revealed in this ASD group.

8.1.2 Future Extensions of the Research

The theoretical explanation as to why the individuals with autism provided a correct verbal response without generating a gestural response lies in the difficulty of the synthesis of gestural processing demands similarly to the recent reported studies in language processing (Mason, Williams, Kana, Minshew, & Just, 2008). Mason and colleagues (2008) suggest that as the processing load increases, individuals with autism may not possess the ability to recruit the required additional mechanisms necessary for adequate performance (Mason et al., 2008; Williams & Minshew, 2007). This verbal response only pattern may be

considered as an extension of Williams and colleagues who found that in tasks of discourse processing, the individuals with autism used a processing pattern for discourse that the typically developing controls only used for the most difficult condition (Williams et al., 2007; Mason et al., 2008). The individuals with autism showed more right hemisphere activation during fMRI studies suggesting that they found this task more difficult. Whereas the control participants recruited a region involved in theory of mind (TOM) processing only when it was appropriate (right temporo-parietal junction), the participants with autism recruited this area even when processing physical inferences. In other words, they recruited the TOM network even when it was not necessary. Differing from previous studies suggesting that individuals with autism do not activate the TOM network, these findings show that they do activate the regions, but they demonstrate an inefficient processing pattern and actually work harder to complete the same task than the typically developing controls.

Similarly, in tasks of intransitive gesture production, the individuals with autism demonstrated difficulty generating a gesture even when they could verbally produce a socially appropriate response, suggesting that when the gestural production tasks necessitated simultaneous and instantaneous processing as well as the recruitment of social cognitive skills, the individuals with autism were already at their limit in terms of using their social cognitive resources and this pattern of praxis processing emerged. Moreover, this pattern suggests that individuals with autism may demonstrate difficulty simultaneously processing and integrating the two different types of information (verbal and gestural) as well as the ability to represent their conceptual knowledge one modality at a time (D. Williams, personal communication September 8, 2009).

Since the individuals demonstrating this error pattern provided the correct verbal response to the social scenario, the comprehension of the social situation was not the problem and one hypothesis may be that individuals with autism possess the ability to represent their conceptual knowledge one modality at a time. This should be a testable hypothesis. A test could be designed to assess the

individuals' gestural performance when cued to 'show' or demonstrate a gesture; when cued to verbally provide a response; and when cued to 'show' and 'tell' simultaneously (D. Williams, personal communication September 8, 2009). Moreover, tasks measuring verbal fluency, underlying cognitive mechanisms including visual perception, motor skills, and visual motor integration, could also be included to determine if those measures predict performance on the cued tasks.

Another extension of this research to be considered in future testing includes the relationship between dyspraxia and apraxia of speech and the relationship between dyspraxia and gestures used in natural conversation. Differing from adult patients with aphasia and limb apraxia who used gesture spontaneously in natural conversation, the individuals with autism often demonstrated awkward bodily positions and held their hands at their sides without using spontaneous gestures during conversational speech. Studies in adult neurogenic patient populations suggest that "praxis and conversational gesture rely on different underlying processing" and that the performance of gesture in natural conversations may actually provide a more valid way to measure gesture treatment than the performance of gesture in limb apraxia tests alone (Rose & Douglas, 2003 p. 453). The authors did not find any relationship between scores on limb apraxia tests and natural gesture use. This would be an interesting follow-up study to conduct in individuals with autism.

8.1.3 Clinical and Therapeutic Implications of the Findings

The information gained from praxis processing and imitation research in individuals with autism may inform future therapeutic interventions for developmental dyspraxia. Differing from apraxia diagnosis in adult patient populations, developmental dyspraxia has often been considered as a unitary disorder therefore, various patterns of praxis processing have not been identified in developmental disorders. In adults, interventions are based on the unique praxis profiles but in developmental populations, treatment is typically not individualised for the particular syndrome (i.e., ideomotor vs. ideational).

In this study, as a group, the individuals with autism performed all of the tasks more poorly than their TD counterparts, but when the individual patterns of praxis processing were identified, it was determined that individuals failed the tasks for different reasons. For example, the cognitive model is a top-down model of praxis processing; therefore it predicts that participants who fail the comprehension tasks subsequently fail the production and imitation tasks as well. This is useful information when planning treatment and intervention, because a participant with gesture comprehension deficits would benefit from an approach focusing on comprehension of the gestures prior to therapy targeting gesture production. Conversely, participants who were able to discriminate and comprehend meaningful gestures without difficulty, but demonstrated impairments in production in one modality over another would benefit from a therapy targeting the strongest modality first and then progressing to an intervention focusing on the weaker modality. Also, if an individual was impaired in one gesture category versus another (i.e., intransitive but not pantomimes), then an intervention specifically tailored to their individual needs could be designed and implemented.

8.1.4 Limitations of the Tasks and Methodology

A few limitations of the methodology used in the present study should be addressed. These limitations do not undermine the findings, but rather provide directions for the development and improvement of the methodology and paradigm for further research. A first limitation of the study is that the battery of tasks was not normed (See section 4.3 for a discussion of the apraxia battery). This may also be considered as an extension of the study because norming the tasks is the next logical step in the progression of the research. The tasks were designed to test different gesture categories and modalities. The intransitive gesture production task in visual modality required social scenarios to properly evaluate and was tested using videoclips, whilst the pantomime production task was tested using objects for the participants to view. The intransitive gesture

videoclips ranged in length from five to seventeen seconds whilst the objects were held in plain view for the participants' to see for a matter of approximately five seconds, therefore differing in the stimuli presentation time.

A second limitation of the study was that the recognition and comprehension tasks differed in terms of recall demands. In the recognition tasks, participants were asked to state whether a gesture was familiar or unfamiliar, thereby requiring them to recall previously seen gestures (free recall). In contrast, the comprehension tasks required the participants to choose the correct response given a series of four choices, a forced choice paradigm requiring recognition recall. According to the cognitive model which is a top-down model of praxis processing, a deficit of gesture recognition would be coupled with a deficit in gesture comprehension. However, when analysing the individual praxis profiles, it was revealed that some participants performed above cutoff in tasks of comprehension whilst failing the recognition tasks, a pattern not explained by the cognitive model. Therefore, it appears that this pattern can be explained when considering the recall differences between the two tasks.

The next limitation was considered when designing the apraxia battery. One argument against using different objects across the different tasks is that it is unknown whether a participant failing to accurately perform an action with an object in one modality (i.e., visual) would accurately perform the same action with the same object in another tested modality (i.e., verbal). However, because the items were used in three tasks of recognition, three tasks of comprehension, and production across visual, verbal, tactile, and imitation modalities, the stimuli were presented multiple times. The concern was that the participants would become overly familiar with the objects, possibly performing the actions correctly based on previous trials rather than a strength or weakness in one modality over another.

8.2 RELATIONSHIP OF THE FINDINGS TO MODELS OF LIMB APRAXIA

8.2.1 Theoretical Implications of the Findings

According to Buxbaum et al. (2005), ideomotor apraxia is a deficit in stored representations of the position and movements of the limbs (especially the hands) subserving skilled object related actions. The authors suggest that ideomotor apraxia reflects deficient inferior parietal representations subserving the production, imitation, and recognition of skilled object-related pantomimes. Patients with ideomotor apraxia demonstrate deficits in producing familiar object related gestures in tasks of pantomime production in both verbal and visual modalities (Bartolo et al., 2008; Buxbaum et al., 2005). In order to address the dissociation in performance between intransitive gestures and pantomimes, Buxbaum and colleagues (2005) stated that in dual-route models of praxis processing, gesture imitation can be accomplished via a direct route which bypasses “representational knowledge but permits calculation of the current position of the actor’s body parts in space and transformation of these coordinates into a body-centered system of coordinates appropriate for the observer’s actions” (Buxbaum et al., 2005 p. 231). The authors suggest that in the dual-route model, this indirect route should be able to be used for imitation of meaningful or meaningless gesture but that the imitation of pantomimes appears to be differentially affected. Therefore, the authors purport that since the performance of transitive imitative gestures (pantomimes) is worse than intransitive gestures, that the deficit must be attributed to another process other than the direct route.

Buxbaum et al. (2005) suggest that the object-hand relationship is developed from an evolutionary primitive system; a preexisting motor system in the inferior parietal lobe designed specifically for human tool uses and object grip. The specific deficits in hand configuration as well as the impairment in both recognition and production tasks suggest damage to the “representations underlying knowledge of hand postures for functional object interactions” and that the inferior parietal lobe

is the location that mediates this relationship between the ventral (e.g., object identification) and dorsal stream (e.g., object use: Buxbaum et al., 2003 p. 1109). However, Buxbaum et al. (2005) report that this system is ‘uniquely human’ and is an elaboration of the basic mirror neuron system; that it involves a more complex system than the mirror neurons alone secondary to the representations coding for both hand and body postures and that these representations can be recruited even when the object is not present (Buxbaum et al., 2003; Buxbaum et al., 2005). Intransitive gestures are not considered to be as strongly associated with evolution and therefore not strongly tied to the left hemisphere.

The authors derived several predictions from their hypothesis. They predicted that patients with limb apraxia would be ‘disproportionately impaired’ in the imitation of transitive (pantomime) versus intransitive gestures (Buxbaum et al., 2005 p. 228) and that these patients would present with hand posture errors. They also predicted that an association between the recognition and imitation of transitive (pantomimes) gestures would be identified as well as an association between hand posture errors and pantomime imitation. Finally, the authors predicted that the association between pantomime recognition and intransitive gesture imitation would be considerably weaker and that patients with hand posture recognition and production errors would have lesions in the left inferior parietal lobe. The findings of their study were consistent with the predictions and the authors purported that representations of object related gestures (pantomimes) are closely tied to pre-existing primitive motor systems controlling object grasping.

Interestingly, Goldenberg (1999) also suggested that the left inferior parietal lobe was implicated in the imitation of hand postures over finger positions. Both theories highlight the coding of information pertaining to the position of the hand and Buxbaum et al. (2005) stress the relationship to object-related gestures.

These current results follow Buxbaum and colleagues (2005) predictions. The individuals with autism were “disproportionately impaired” in pantomime imitation compared to intransitive gesture imitation and they presented with hand

posture errors. Moreover, an association was identified between pantomime imitation and pantomime recognition as well as in hand posture errors and pantomime imitation in the ASD group. Finally, there was not a significant association between pantomime recognition and intransitive gesture imitation.

However, the relationship between recognition and imitation in apraxia has been informed by different theories. The second predominant theory addressing the relationship between these underlying gestural representations subserving production and gesture recognition have also been explained using cognitive models of gesture processing in adult brain damaged patient populations (Bartolo et al., 2008; Cubelli, et al., 2000; Rothi et al., 1991). The discovery that patients with lesions in the parietal lobe presented with both recognition and production errors whereas patients with anterior lesions involving the frontal lobe demonstrated only imitation deficits but not discrimination errors provided the foundation for the first cognitive neuropsychological model of praxis processing in adults (Rothi et al., 1991). In 2000, Cubelli and colleagues modified Rothi's model using cognitive concepts to better explain the resulting dissociations of praxis processing patterns. To date, this is the first reported finding of an association between pantomime recognition and pantomime imitation in ASD and suggests that the patterns of performance observed in the ASD group are similar to patterns observed in apraxic patients (see section 5.2.4 for a discussion of the relationship between recognition and imitation in apraxia).

In summary, in this study, the individuals with ASD performed all tasks more poorly than controls; however, their imitation performance could not be fully explained by the cognitive measures included in the regression model. Further, analysis of the error types revealed similarities to documented cases of limb apraxia in adults. Deficits in pantomime imitation (Bartolo et al., 2003), findings of hand posture errors including spatial errors (e.g., hand configuration, amplitude, and distance errors: Buxbaum et al., 2005; Rothi et al., 1991); body part as tool errors (Bartolo et al., 2003); temporal errors including timing; associations between pantomime imitation and recognition; have all been demonstrated in patients with

limb apraxia (Bartolo et al., 2008; Cubelli, et al., 2000). These same characteristics were observed in this sample of individuals with autism. Taken together, these findings suggest that some individuals with autism may present with characteristics consistent with dyspraxia and that further study is encouraged to identify the specific subgroup of individuals with autism presenting with concomitant developmental dyspraxia.

8.2.2 Possible Adaptation of the Cognitive Model

TG, KK, BH, and DS, performed above cutoff in tasks of recognition and comprehension indicating that the input lexicon and action semantic were not impaired. All participants also produced meaningless gestures without difficulty suggesting that the deficit did not lie at the level of the visuomotor conversion mechanism.

Interestingly, the participants made errors of the hand, arm, timing, and BPO (body part as object). It has been suggested that BPO errors may be a compensatory strategy allowing a participant to rely on an intact semantic system to produce a gesture (Bartolo et al., 2003). BPO errors contain semantic information related to object function but the hand configuration is not produced correctly (Bartolo et al., 2003). Subsequently, the presence of this error type would suggest that the lexical route was recruited for imitation.

The fact that pantomimes were comprehended and produced to verbal command without difficulty would indicate that they reached the action semantic allowing for processing and gesture production along the lexical route. Explaining this pattern of production appears to be challenging because pantomime imitation was impaired. Since pantomime imitation was impaired this may suggest that a deficit at the level of the output lexicon specifically for imitation is implicated. It is important to note that in the ASD group, the opposite pattern did not exist; preserved pantomime imitation in the presence of impaired pantomime production.

Ochipa, Rothi, & Heilman, (1990; 1994) published their findings of a patient presenting with a pattern of performance characterised by spared gesture comprehension and production to verbal command with impaired pantomime imitation performance. They named this pattern of apraxia, Conduction apraxia and compared it to a pattern of conduction aphasia, a language disorder believed to be the result of damage to association fibers connecting Wernicke's to Broca's area. The authors suggested that similarities exist between the two disorders and cite Strub and Gardner's (1972) suggestion that the verbal repetition deficit in aphasia occurs after auditory input at the phonemic level but before the phonemes are encoded in production (Ochipa et al., 1994).

Therefore, explaining this pattern of impaired imitation with better pantomime production to verbal command, the authors posited that the deficit would have to occur at some point *at* or *after* the action lexicon suggesting that verbal command can bypass the input lexicon. The authors suggested that difficulty with pantomime imitation in this case may be explained by "increased production difficulty resulting from additional problems arising before access to the action output lexicon" (Ochipa et al., 1994, p. 1242). However, it is not clear what additional problems may have occurred. The authors stated that a single impairment of gesture imitation is not well described by the model (Ochipa et al., 1994).

Bartolo et al. (2003) reported that at the procedural level, motor programmes for intransitive and transitive gestures differ, and Cubelli et al. (2000) have reported patients with selective output lexicon impairments for transitive and intransitive gestures respectively. One possibility is that this type of hypothesis may extend to modality as well. Certainly, there is evidence of selective input and dissociations have been reported in verbal, visual, and tactile (De Renzi et al., 1982) modalities. It has been suggested that there is a "fractionation of input modalities feeding into the action input lexicon suggesting that the input systems to the action lexicon should be specified for modality as well as the nature of the input material"

(Rothi, Ochipa, & Heilman, 1997, p. 41).

In this study, only TG demonstrates a deficit in the pantomime in imitation modality as described by Ochipa and colleagues (1994) but the idea that the deficit would have to occur after the action semantic and that fractionation of input modalities feeds into the action input lexicon, would lend itself to the possibility of considering fractionation of output modalities at the level of the action output lexicon as well to explain the other error patterns (TG failed the object imitation task secondary to behaviours associated with autism).

Following Bartolo et al., (2001) if the lexical route was recruited in the tasks of meaningful gesture imitation as evidenced by BPO errors, a fractionation of imitation and production would have to occur after the action semantic because comprehension tasks were performed without difficulty. One hypothesis is that the difficulty lies at the level of the action output system with possible fractionation of modalities. Currently, the model does not account for fractionation of the action output system similarly to the fractionation of the input system and the action semantic system. Perhaps this might be one explanation for this pattern of praxis processing.

8.3 APPLYING MODELS BASED ON ADULT ACQUIRED DISORDERS TO DEVELOPMENTAL DISORDERS

Differences exist between adult and paediatric brain neurocognitive processing and it is well-known that neuropsychological disorders with similar behavioral performance may arise from different underlying neurological etiologies. For this reason, some researchers argue that similar interpretations as in adult populations cannot apply to paediatric populations (Karmiloff-Smith, Scerif, & Ansari, 2003). However, even when the underlying etiologies are different, the current trend is to focus on the similarities between adult and child disorders in order to gain a deeper understanding of the disorder under exploration. For example, in the study of apraxia, developmental researchers are now borrowing models from adult

neuropsychological studies of limb apraxia to use in the paediatric population (Dewey, 1995; Mostofsky et al., 2006; Smith & Bryson, 2007). Similarly, the application of knowledge from one population to another is evidenced in adult patients with left cerebrovascular accidents (CVA) as new treatments are being implemented in adult patients based on the latest findings of paediatric brain recovery (Schlagger, Brown, & Luger, 2002).

Karmiloff-Smith and colleagues have argued that in neuropsychology, dissociations are considered “bread and butter” and double dissociations “chocolate cake” (Karmiloff-Smith, Scerif, & Ansari, 2003 p. 161). One argument against the use of dissociations in developmental populations is the way in which an uneven cognitive profile has been described in individuals with autism. For example, Karmiloff-Smith and colleagues (2003) argue that an uneven cognitive profile observed in individuals with autism is the result of differences in the underlying organisation and functioning of neurocognitive processing and not of any ‘sparing’ of cognitive functioning (Karmiloff-Smith, 1998). The ‘sparing’ of cognitive functioning appears to be a main area of concern of Karmiloff-Smith et al. (2003) because they do not agree that the ‘intact’ modules are truly intact and that the paediatric brain is not specialised and localised as it is in adults. Further, the authors state that the identification of double dissociations in developmental disorders rests on a ‘false assumption’ that the cognitive processes are either ‘impaired’ or ‘intact’ and that individuals performance is placed into neat little boxes of cognitive modules resulting in an interpretation that fails to consider ontogenic development (Karmiloff-Smith et al., 2003, p. 161).

The above points are very important areas to consider when applying adult cognitive models to developmental patient populations. Specially, the identification of dissociations appears to be a controversial topic, even though the design of an overall "profile" of a child's strengths and weaknesses is "current recommended practice" and is also required by law (Individuals with Disabilities Education Improvement Act of 2004: Crais, Watson, & Baranek, 2009, p. 95).

After careful review of the literature, there appears to be inconsistencies regarding the operating definition as well as the theoretical underpinnings of the identification of dissociations in developmental studies.

In order to address these arguments, it is best to begin with the operational definitions of the various types of dissociations. The conventional definition of a *classical* dissociation is used to describe an observed pattern of performance when an individual's performance is impaired in Task X but is not 'impaired' or 'is within normal limits' on task Y when compared to a control group (Shallice, 1988). However, Crawford and Garthwaite (2006) suggest that this definition of a classical dissociation be modified. Therefore, the authors purported using new criteria that would require methods based on t-distributions. The new classification would require that the participant demonstrate a statistical difference (standardised difference) between the scores of task X and task Y that would differ from the standardised differences in the two tasks in the control group *and* that the patient demonstrate a significant difference between at least one of the tasks when compared to the control group.

A double dissociation, on the other hand, is a reversed pattern of an identified dissociation. For example, an individual performs task A within normal limits while task B is impaired, and another individual performs within normal limits of B while task A is impaired. Dissociations can be identified in individual or group results. Additional terms used to capture differences in task performance have included terms such as fractionation, selective impairment, and task dependency (Bartolo, Cubelli, Della Sala, & Drei, 2003; Hamilton, Brindley & Frith, 2007; Hamilton, 2008).

Indeed, it is inappropriate to identify a dissociation or a double dissociation with the goal of describing an 'intact' cognitive module without understanding the underlying cognitive mechanisms and taking into account the entire cognitive profile and developmental trajectory of the individual. Karmiloff-Smith et al. (2003) state that "without a developmental account of the underlying mechanisms,

it is impossible to account for performance differences within and between developmental disorders in terms of selectively spared or impaired modules” and that the results of the ‘intact’ modules are only as sensitive as the measurement used for the assessment (Karmiloff-Smith et al., 2003, p. 161). Again, this is a very critical point, it is imperative to consider *development* in development disorders. However, it is also well-known that many individuals with developmental disorders, including autism, display a unique and often uneven developmental trajectory, including language development, including not only developmental delays but also deviant and disordered patterns of development (Joseph, Tager-Flusberg, & Lord; Lord, 2001). This is not to suggest that a delay is not an integral part of understanding the complexity of developmental disorders. On the contrary, it is crucial to take into account the developmental trajectory as well as to take into account the underlying cognitive mechanisms that may affect individual differences in performance, including measures such as visual perception, visual motor integration, language, and working memory (Dewey, 1995; Smith & Bryson, 2007).

Therefore, the first step in a well-designed research protocol, especially when administering adult models to paediatric populations, is to interpret all results through a developmental filter. The most important consideration when discussing dissociations in developmental disorders is first, to determine the definition of dissociation used by the authors of a study, and second, to determine the reasons behind the identification of the dissociations and how they were applied to the pertinent research questions. In autism research, it appears that dissociations are identified for three main reasons. First, to discuss cognitive functioning in autism, second, to identify potential areas in which to target therapeutic intervention, and third to identify patterns of performance that may be indicative of subgroups of autism as well as to further inform the distinction between autism and Asperger’s Syndrome. Dissociations are often reported at the group level (Brewer, Brereton, & Tonge, 2008; Pellicano, 2007), individual level (Ghazziudian, 2008; Kuschner, Bennetto, & Yost, 2006), as well as a combination of group level and individual dissociations (Hill & Bird, 2006; White, Frith,

Milne, Rosen, & Swettenham, 2006). The goal of the study should drive the design and the choice of appropriate use of dissociations.

To highlight the difference types of use of dissociations in developmental studies, one group and one combination study (including both group and individual differences) appeared to be useful examples and the arguments the authors used to discuss their results will now be outlined in turn.

The first study was an experimental design testing two different types of working memory; verbal and spatial (Williams, Goldstein, Carpenter, & Minshew, 2005). The first important observation to highlight regarding this study is that Williams et al. (2005) included a carefully selected control group matched on age, gender, and various measures of cognition while Karmiloff-Smith et al. warned of identifying dissociations when comparing groups by mental age. The logic followed that if Mental Age was used to match two groups, one clinical and the other typically developing (TD), and task A was performed similarly in both groups while task B was not, then describing the discrepancy as dissociation would be erroneous. In this case, they suggested, the use of the word 'delay' would be more appropriate because the clinical group would presumably be much older than the TD group and would be delayed in both tasks, but with a greater delay in task B. However, in our example study, this is not a concern because the control group was well-matched on more measures than mental age and was even divided into two groups; one group for children and adolescents, and the other for adults.

Regarding the interpretation of findings determining underlying cognitive functioning, Williams and colleagues (2005) designed a battery of tasks around aspects of a working memory model developed by Baddeley (Baddeley, 1986 cit. in Williams, Goldstein, Carpenter, & Minshew, 2005). Verbal and spatial working memory tasks were administered to the autism and control groups and the results revealed that the autism group performed similarly to the matched control sample (no statistical differences) in the measures of verbal working memory but not in tasks of visual spatial memory (statistically significant differences). The

authors reported that there was a group level dissociation, in other words there was a dissociation of performance in Task A in the autism group when compared to the performance of the control group, but not of Task B. Williams et al (2005) made a case for the integrity of one system versus the impairment of another, and used evidence to discuss their findings, importantly, they did not draw conclusions based on one 'intact module'. The information gleaned from the identified group dissociation was used to further explore the nature of the observed deficits in autism while the autistic individuals performed planning tasks that required increased cognitive complexity. It is important to note that inherent in the design outcome was the identification of dissociations within the autism group.

Regarding the interpretation of findings determining underlying cognitive functioning, the authors specifically designed a battery of tasks around aspects of a working memory model developed by Baddeley (Baddeley, 1986 cit. in Williams et al., 2005). Verbal and spatial working memory tasks were administered to the autism and control groups and the results revealed that the autism group performed similarly to the matched control sample (no statistical differences) in the measures of verbal working memory but not in tasks of visual spatial memory (statistically significant differences). The authors reported that there was a group level dissociation; in other words there was a dissociation of performance in Task A in the autism group when compared to the performance of the control group, but not of Task B. This is slightly different than reporting single case dissociations where Task A is significantly different from Task B and Task A differs from the control group. Most likely, Task A and B are statistically different in the autism group but it is not reported. This is not a single case approach and would not follow the previous definitions reported by Crawford & Garthwaite (2006).

Only after taking the first step in comparing the results of the autism group to the well-matched control group do the authors begin to discuss the differences in performance between the two tasks (i.e. verbal and spatial working memory). Then by reporting evidence of previous findings of similar studies, the authors

make a case for the preserved integrity of verbal working memory in autism. They then followed the same approach in describing the impairment of spatial working memory in autism and then exploring the possible theoretical explanations behind the observed difference in performance between the two tasks; thoroughly investigating the dissociation in performance of verbal and spatial working memory. At the end of the discussion the authors hypothesize about what this pattern of performance may suggest in relation to neurobiological differences in the two types of working memory. Williams et al made a case for the integrity of one system versus the impairment in another and used evidence to discuss their findings; they did not draw conclusions based on one 'intact module'. Importantly, the information gleaned from the identified group dissociation was used to gain a deeper understanding of the nature of the observed deficits when individuals with autism perform tasks in planning that require increased cognitive complexity. It is important to note that inherent in the design outcome was the identification of dissociations within the autism group.

In another study, White and colleagues (2006) tested literacy and sensorimotor abilities in individuals with dyslexia and autism, then compared their performance to typically developing children. The analysis unfolded in an elegant and systematic fashion beginning with between group analyses and ending with individual comparisons. The authors tested literacy and sensorimotor abilities in individuals with dyslexia, autism, and compared their performance to typically developing children. They began by using ANOVAs to determine between group differences, but changed the alpha level to .01 to account for multiple comparisons. Next, they identified outliers using the cutoff of 1.65 standard deviations below the mean. Literacy, phonology, auditory, visual, and motor factors were calculated combining various test scores and a z score was also calculated in comparison to the control group performance. Because the literacy score was correlated with non verbal IQ, after regression analysis using nonverbal IQ as a independent variable, new literacy factor was obtained and all other summary factors controlled for nonverbal IQ. The autism group was divided using the criteria for outliers in two groups; autism good readers and autism poor

readers. After each group analysis, the individual outliers were identified. Next, correlations were performed to explore the relationship between the different sensorimotor variables and literacy and were followed by a multiple regression analysis that used the literacy variable as the dependent variable and the sensorimotor variables as predictors of the literacy variance.

The individual performance of each child was then thoroughly investigated and all children were grouped according to their performance in each of the different tasks. The three groups were compared; 48% of dyslexics, 54% of autistic poor readers, and 67% of autistic good readers had one or more sensorimotor impairment. Fifteen percent of the control group demonstrated one or more sensorimotor impairments as well. Results revealed that there did not appear to be any relationship between reading impairment and sensorimotor impairments. Indeed, double dissociations were identified between the two areas. Six autistic children demonstrated sensorimotor impairments but their reading skills were within normal limits while 12 dyslexic children without any sensorimotor impairment demonstrated deficits in reading skills.

Importantly, the authors discussed the statistical approach used in the identification of the double dissociation. The authors acknowledged that some may criticize their report of a double dissociation “for setting arbitrary deviance thresholds and artificially splitting the subjects into impaired and intact categories, while there might be little difference between subjects whose scores are just above or below the thresholds” (White et al., 2006, p. 757). The authors built a strong case for the evidence of the identification of the double dissociation. They pointed out that the numbers (6 vs. 12) on each side of the dissociation make it difficult to disregard the finding as an artifact of thresholds and many of the dissociations well exceeded the threshold used in making the determinations.

The second reason that the identification of dissociations is an important area for consideration in developmental disorders is their usefulness in effective treatment planning (Crais & Roberts, 2004; Crais, Watson, & Baranek, 2009; Lord, 2001;

Tager-Flusberg, 2004; Wetherby, Prizant, & Hutchinson, 1998). When working with a heterogeneous population such as autism, it is imperative to determine the “peaks and valleys within a child’s own profile” not only at the group level but on an individual basis as well (Kuschnier, Bennetto, & Yost, 2006, p. 795). As a starting point for treatment, the identified strengths can be used to scaffold the weaknesses (Lord, 2001). For example, if visuo-spatial skills are strength for a child, then reading at word level may provide cues for social behavior in school and community settings; if a child demonstrates superior skills in auditory memory then this strength may be used to design appropriate phrases in social situations (Lord, 2001). Only after administration of a complete battery of tasks, can a detailed account of an individual’s strengths and weaknesses be identified thereby lending itself to the development of a unique cognitive profile. Perhaps the best way is to consider dissociations in developmental populations using this approach is to interpret the results as a ‘snapshot in time’ of an individual’s current level of functioning with the clear understanding that this profile will not remain the same throughout development. This is not to suggest that the pattern or profile will remain consistent throughout the lifespan as some have expressed concern that “genetic disorders tend to take for granted that the disorder manifests a similar pattern in infancy as in adulthood” (Karmiloff-Smith, 2003, p. 162). It may be considered as a starting point to document observed strengths and weaknesses that may be included in a cognitive, gestural, or language profile. The development of therapeutic interventions cannot take for granted a “typical sequence of learning” but rather must be tailored to each individual, paying attention to their individual strengths and weaknesses that may then be applied to relevant and functional goals for the child (Lord, 2001).

The third reason that the identification of dissociations is a useful tool in developmental disorders, especially in autism spectrum disorder (ASD), is to inform the identification of autism subgroups. Addressing heterogeneity within the autism spectrum is challenging, but it is critical to study the heterogeneity itself. As highlighted by Tager-Flusberg (2004), only by investigating heterogeneity directly, is it possible to identify more homogenous subtypes within

the population, and in turn, these homogenous subtypes can help in understanding the genetic and neurobiological basis of autism. The author described specific patterns that have been identified in language functioning in ASD, highlighting the dissociation between pragmatic and lexical components. Again, combinations of within-group followed by between-group designs have been proposed. Tager-Flusberg (2004) identified three different language subgroups when analysing the profiles; a normal language subtype, an impaired language subtype, and the borderline subtype. Moreover, upon closer inspection of the impaired language subtype an interesting profile was revealed: Unimpaired articulation was identified in the presence of poorer performance of high level syntactic and semantic tests than in vocabulary tests (Tager-Flusberg, 2004). The author revealed that this profile was similar to previously identified language profile in Specific Language Impairment.

Dissociations in task performance have also been used to distinguish individuals with autism from those with Asperger's Syndrome (AS). Dissociations in performance between verbal IQ (VIQ) and performance IQ (PIQ) have been measured in both groups (Ghaziuddin & Mountain-Kimchi, 2005). Results indicated that in individuals with AS, 82% of the cases tested scored higher in tasks of VIQ than PIQ and 10 of the cases showed a greater than 10 point split. Fifty percent of individuals with high-functioning autism also scored higher in tests of VIQ but interestingly, the split was minimal (Ghaziuddin & Mountain-Kimchi, 2005) leading the authors to suggest that individuals with a higher VIQ than PIQ score may support a definition of AS but it is not definitive. Social interaction was recently used to compare individuals with autism and AS (Ghaziuddin, 2008). The author's preliminary findings suggest that indeed there does appear to be a distinction; specifically, that individuals with AS tend to be 'active but odd' whereas individuals with autism tended to be 'aloof and passive' (Ghaziuddin, 2008). These findings suggest that dissociations in patterns of social interaction may also be important in accurate diagnosis and classification of AS versus autism.

In summary, the use of adult models in developmental populations and subsequent identification of dissociations for both clinical and research purposes, is an essential tool that provides information that addresses the overall functioning of individuals across the spectrum. The identification of dissociations has proven to be useful in exploring underlying cognitive functioning, revealing patterns of performance in establishing a unique cognitive profile, distinguishing between subgroups of autism, as well as informing differentiation of AS from autism. Given the heterogeneity of the autism population, identification of dissociations appears to be not only appropriate, but good research practice especially when the information is incorporated into therapeutic intervention or used to address specific theoretical questions. In this study, patterns of praxis processing have been identified in individuals with autism that can now be further explored in future studies. Possible future assessment tools therapeutic interventions can now be designed around the components of the cognitive model.

ACKNOWLEDGEMENTS

This work would never have been completed if it weren't for the support and guidance from a team of researchers who have guided and directed me over the years.

First, I would like to thank Martin Corley, PhD for taking me on as a student when I did not have a supervisor, and for encouraging me to look at problems from more than one perspective. Martin challenged me to look critically at my own work, and for this I am truly grateful. I am deeply indebted to Angela Bartolo, PhD for training me in the administration and development of the apraxia battery and for tirelessly answering all of my questions. She also provided me with unlimited support, guidance, and attention throughout my years as a PhD student. Moreover, I am indebted to Sara Swanson, PhD at the Medical College of Wisconsin, for not only offering to be the principal investigator for the IRB, but for always believing in me, advising me, and being an incredible role model and mentor. This work would not have been possible without the expertise of Aniko Szabo, PhD at the MCW for her wisdom and ability to understand and fit logistic regression models. Also, thank you to Thusa Rajendran, PhD and Jean Carletta, PhD who also participated significantly in my supervision and provided invaluable support toward the completion of this work. I would like to acknowledge Professor Sergio Della Sala for all of his encouragement and I want not want to forget to mention Deborah Pearson, PhD and Diane Williams, PhD, two autism researchers who have been enthusiastic and supportive of my work.

Of course, I would like to thank all of the families for participating in the study and those who were involved in the design of the apraxia battery. Special acknowledgement goes to my nephew, Nicholas Ham, who was diagnosed with autism at the age of three. Big thanks to all of my friends and family who have been there for me and cheered me on throughout this process.

Above all, I would like to dedicate this thesis to my loving husband, Bilen Ham, without whom I would never have been able to accomplish this important life goal. I am extremely grateful for all of his hard work, sacrifice, undying support, and patience during these last several years. Finally, I do not want to forget to remember my late mother and father, both of whom I know would have been very proud to know that I have finally completed this work.

REFERENCES

- American Psychiatric Association, (1994). Diagnostic and statistical manual of mental disorders (4th edn. DSM-IV). Washington DC: Author.
- Abrahamsen, E., & Mitchell, J. (1990). Communication and sensorimotor functioning in children with autism. *Journal of Autism and Developmental Disorders*, 20(1), 75-85.
- Abravanel, E., Levan-Goldschmidt, E., & Stevenson, B. (1976). Action imitation: The early phase of infancy. *Child Development*, 47(4), 1032-1044.
- Alloway, T.P., Rajendran, G., & Archibald, L.M.D. (in press). Working memory in children with developmental disorders. *Journal of Learning Disabilities*.
- Avikainen, S., Wohlschlager, A., & Hari, R. (2003). Impaired mirror-image imitation in Asperger and high-functioning autistic subjects. *Current Biology*, 13, 339-341.
- Ayres, A.J. (1972). Sensory integration and learning disorders. Los Angeles: Western Psychological Services.
- Baird, G., Simonoff, E., Pickles, A., Chandler, S., Loucas, T., Meldrum, D., & Charman, T. (2006). Prevalence of pervasive developmental disorders in a population cohort of children in Southeast Thames. *The Lancet*, 368, 210-215.
- Baldwin, M. (1892). Infants' Movements. *Science*, 19, 15-16.
- Barbieri, C., & De Renzi, E. (1988). The executive and ideational components of apraxia. *Cortex*, 24, 535-553.
- Baron-Cohen, S. (1995). Mindblindness: An essay on autism and theory of mind. Cambridge, MA: MIT Press.
- Baron-Cohen, S. (1988). Social and pragmatic deficits in autism: Cognitive or affective? *Journal of Autism and Developmental Disorders*, 18, 379-402.
- Baron-Cohen, S., Leslie, A.M., & Frith, U. (1985). Does the autistic child have a "theory of mind"? *Cognition*, 21, 37-46.
- Bartak, L., Rutter, M., & Cox, A. (1975). A comparative study of infantile autism and specific developmental receptive language disorder. *The British*

Journal of Psychiatry, 126(2), 127-145.

- Bartolo, A. (2002). Apraxia: New tests for the assessment of a cognitive model and the evaluation of the semantic system. Unpublished PhD thesis, Aberdeen University, UK.
- Bartolo, A., Cubelli, R., Della Sala, S., Drei, S., & Marchetti, C. (2001). Double dissociation between meaningful and meaningless gesture reproduction in apraxia. *Cortex*, 37, 696-699.
- Bartolo, A., Cubelli, R., Della Sala, S., & Drei, S. (2003). Pantomimes are special gestures which rely on working memory. *Brain and Cognition*, 53, 483-494.
- Bartolo, A., Cubelli, R., & Della Sala, S. (2008). Cognitive approach to the assessment of limb apraxia. *The Clinical Neuropsychologist*, 0, 1-19.
- Bartolo, A., Daumuller, M., Della Sala, S., & Goldenberg, G. (2007). Relationship between object-related gestures and the fractionated object knowledge system. *Behavioral Neurology*, 18(3), 143-147.
- Bates, E., & Dick, F. (2002). Language, gesture, and the developing brain. *Developmental Psychobiology*, 40, 293-310.
- Beadle-Brown, J., & Whiten, A. (2004). Elicited imitation in children and adults with autism: Is there a deficit? *Journal of Intellectual and Developmental Disabilities*, 129, 147-163.
- Beery, K., & Beery, N. (2004). *The developmental test of visual motor integration*. Los Angeles, CA: Western Psychological Services.
- Bekkering, H., Wohlschlager, A., & Gattis, M. (2000). Imitation of gestures in children is goal directed. *Quarterly Journal of Experimental Psychology*, 53A, 153-164.
- Bennetto, L., Pennington, B., & Rogers, S. (1996). Intact and impaired memory functions in autism. *Child Development*, 67, 1816-1835.
- Berges, J. & Lezine, I. (1965). *The imitation of gestures*. London: The Spastics Society Medical Education and Information Unit with William Heinemann Books Ltd.
- Brewer, W.J., Brereton, A., & Tonge, B.J. (2008). Dissociation of age and ability on a visual analogue of the University of Pennsylvania smell identification

- test in children with autism. *Research in Autism Spectrum Disorders*, 2(4), 612-620.
- Buxbaum, L.J., Sirigu, A., Schwartz, M.F., & Klatzky, R.L. (2003). Cognitive representations of hand posture in ideomotor apraxia. *Neuropsychologia*, 41, 1091-1113.
- Buxbaum, L.J., Kyle, K., & Menon, R. (2005). On beyond mirror neurons: Internal representations subserving imitation and recognition of skilled object-related actions in humans. *Cognitive Brain Research*, 25(1), 226-239.
- Buxbaum, L.J., Kyle, K., Grossman, M., & Coslett, H.B. (2007). Left inferior parietal representations for skilled hand-object interactions: Evidence from stroke and corticobasal degeneration. *Cortex*, 43, 411-423.
- Carmo, J.C.C., & Rumiati, R.I.I. (2009). Imitation of transitive and intransitive actions in healthy individuals. *Brain and Cognition*, 69, 460-464.
- Carpenter, M., Pennington, B.F., & Rogers, S.J. (2001). Understanding of others' intentions in children with autism and children with developmental delays. *Journal of Autism and Developmental Disorders*, 31, 589-599.
- Castelli, F., Frith, C., Happe, F., & Frith, U. (2002). Autism, Asperger Syndrome and brain mechanisms for the attribution of mental states to animated shapes. *Brain*, 125, 1839-1849.
- Centers for Disease Control. Autism Information Center.
http://www.cdc.gov/ncbddd/autism/faq_prevalence.htm
- Cermak, S. (1985). Developmental dyspraxia. In E.A. Roy (Ed.), *Neuropsychological studies of apraxia and related disorders* (pp. 225-248). Amsterdam: North Holland.
- Cermak, S., Gubbay, S.S., & Larkin, D. (2002). What is developmental coordination disorder? In: S. Cermak & D. Larkin, (Eds.), *Developmental motor coordination disorder* (pp. 2-22). Albany, NY: Delmar Thomson.
- Chainay, H., & Humphreys, G.W. (2002). Neuropsychological evidence for a convergent route model for action. *Cognitive Neuropsychology*, 19(1), 67-93.
- Chaminade, T., Meltzoff, A.N., & Decety, J. (2005). An fMRI study of imitation,

- action, and body schema. *Neuropsychologia*, 43(11), 115-127.
- Chartrand, T.L., & Bargh, J.A. (1999). The chameleon effect: The perception and behavior link and social interaction. *Journal of Personality and Social Psychology*, 76, 893-910.
- Charman, T. (2003). Why is joint attention a pivotal skill in autism? *Philosophical Transactions: Biological Sciences*, 358(1430), 315-324.
- Charman, T., & Baron-Cohen, S. (1994). Another look at imitation in autism. *Development and Psychopathology*, 6, 403-413.
- Charman, T., Swettenham, J., Baron-Cohen, S., Cox, A., & Drew, A. (2000). Testing joint attention, imitation, and play as infancy precursors to language and theory of mind. *Cognitive Development*, 15(4), 481-498.
- Crais, E., Watson, L., & Baranek, G. (2009). Use of gesture development in profiling children's prelinguistic communication skills. *American Journal of Speech-Language Pathology*, 18, 95-108.
- Crawford, J.R., & Garthwaite, P.H. (2006). Detecting dissociations in single-case studies: Type I errors, statistical power and the classical versus strong distinction. *Neuropsychologia*, 44(12), 2249-2258.
- Cubelli, R., Marchetti, C., Boscolo, G., & Della Sala, S. (2000). Cognition in action: Testing a model of limb apraxia. *Brain and Cognition*, 44, 144-165.
- Cubelli, R., Bartolo, A., Nichelli, P., & Della Sala, S. (2006). List effect in apraxia assessment. *Neuroscience Letters*, 407(2), 118-120.
- Curcio, F. (1978). Sensorimotor functioning and communication in mute autistic children. *Journal of Autism and Developmental Disorders*, 8(3), 281-292.
- Curcio, F., & Piserchia, E.A. (1978). Pantomimic representation in psychotic children. *Journal of Autism and Developmental Disorders*, 8(2), 181-189.
- Dawson, G., Meltzoff, A., Osterling, A., & Rinaldi, J. (1998). Neuropsychological correlates of early symptoms of autism. *Child Development*, 69(5), 1276-1285.
- Dawson, G., & Adams, A. (1984). Imitation and social responsiveness in autistic children. *Journal of Abnormal Child Psychology*, 12(2), 209-226.
- Dawson, G., Munson, J., Estes, A., Osterling, J., McPartland, J., Toth, K., Carver,

- L., & Abbott, R.. (2002). Neurocognitive function and joint attention ability in young children with autism spectrum disorder versus developmental delay. *Child Development*, 73(2), 345-358.
- De Ajuriaguerra, J., & Tissot, R. The apraxias. In: *Handbook of clinical neurology*, 4, P.J. Vinken & G.W. Bruyn (Eds.) North Holland: Amsterdam.
- Della Sala, S., Faglioni, P., Motto, C., & Spinnler, H. (2006). Hemisphere asymmetry for imitation of hand and finger movements: Goldenberg's hypothesis reworked. *Neuropsychologia*, 44, 1496-1500.
- De Renzi, E. (1985). Methods of limb apraxia examination and their bearing on the interpretation of the disorder. In: E.A. Roy (Ed.), *Neuropsychological studies of apraxia and related disorders (Vol. 23)*. Amsterdam: North Holland.
- De Renzi, E., & Faglioni, P. (1999). Apraxia. In: G. Denes & L. Pizzamiglio (Eds.), *Handbook of clinical and experimental neuropsychology* (pp. 421-440). UK: Psychology Press.
- De Renzi, E., & Luchelli, F. (1988). Ideational apraxia. *Brain*, 111, 1173-1183.
- DeMyer, K., Alpern, G., Barton, S., DeMyer, W., Churchill, D., Hingtgen, J., Bryson, C., Pontius, W., & Kimberlin, C. (1972). Imitation in autistic, early schizophrenic, and non-psychotic subnormal children. *Journal of Autism and Childhood Schizophrenia*, 2, 264-287.
- DeMyer, M.K., Hingtgen, J.N., & Jackson, R.K. (1981). Infantile autism reviewed: A decade of research. *Schizophrenic Bulletin*, 7(3), 388-451.
- Dewey, D. (1995). What Is developmental dyspraxia. *Brain and Cognition*, 29(3), 254-274.
- Dewey, D., Cantell, M., & Crawford, S. (2007). Motor and gestural performance in children with autism spectrum disorders, developmental coordination disorder, and/or attention hyperactivity disorder. *Journal of the International Neuropsychological Society*, 13, 246-256.
- Di Pellegrino, G., Fadiga, L., Fogassi, L., Gallese, V., & Rizzolatti, G. (1992). Understanding motor events: A neurophysiological study. *Experimental Brain Research*, 91, 176-180.

- Dumont, C., Ska, B., & Schiavetto, A. (1999). Selective impairment of transitive gestures: An unusual case of apraxia. *Neurocase*, 5, 447-458.
- Duff, S., & Logie, R.H. (2001). Processing and storage in working memory span. *The Quarterly Journal of Experimental Psychology*, 54A, 31-48.
- Duffy, R.J., & Duffy, J.R. (1989). An investigation of body part as object (BPO) responses in normal and brain-damaged adults. *Brain and Cognition*, 10, 220-236.
- Dziuk, M., Larson, J.C., Apostu, A., Mahone, E.M., Denckla, M.B., & Mostofsky, S.H. (2007). Dyspraxia in autism: Association with motor, social, and communicative deficits. *Developmental Medicine & Child Neurology*, 49, 734-739.
- Harrington, D.L., & Haaland, K.Y. (1997). Representations of actions in ideomotor limb apraxia: Clues from motor programming and control. In: L.G. Rothi & K. Heilman (Eds). *Apraxia, the neuropsychology of action* (pp. 111-146).
- Heath, M., Roy, E.A., Black, S., & Westwood, D. (2001). Intransitive limb gestures and apraxia following unilateral stroke. *Journal of Clinical and Experimental Neuropsychology*, 23(5), 628-642.
- Fadiga, L., Fogassi, L., Gallese, V., Rizzolatti, G. (2000). Visuomotor neurons: Ambiguity of the discharge or motor perception? *International Journal of Psychopathology*, 35, 165-177.
- Fadiga, L., Fogassi, L., Pavesi, G., & Rizzolatti, G. (1995). Motor facilitation during action observation: A magnetic stimulation study. *Journal of Neurophysiology*, 73, 2608-2611.
- Faglioni, P., & Basso, A. (1985). Historical perspectives on neuroanatomical correlates of limb apraxia. In: E.A. Roy (Ed.), *Neuropsychological studies of apraxia* (pp. 3-44). North Holland: Elsevier Science Publishers
- Foundas, A., Macauley, B.L., Raymer, A.M., Maher, L.M., Heilman, K.M., & Rothi, L.G. (1995). Ecological implications of limb apraxia: Evidence from mealtime behavior. *Journal of the International Neuropsychological Society*, 1, 62-66.
- Freitag, C., Kleser, C., Schneider, M., & von Gontard, A. (2007). Quantitative

- assessment of neuromotor function in adolescents with high functioning autism and Asperger Syndrome. *Journal of Autism and Developmental Disorders*, 37(5), 948-959.
- Frith, U. (2001). Mind blindness and the brain in autism. *Neuron*, 32, 969-979.
- Frith, U., & Happe, F. (1994). Language and communication in autistic disorders. *Philosophical Transactions: Biological Sciences*, 346(1315), 97-104.
- Fukutake, T. (2003). Apraxia of tool use: An autopsy case of biparietal infarction. *European Neurology*, 49, 45-52.
- Gallese, V., Fadiga, L., Fogassi, L., & Rizzolatti, G. (1996). Action recognition in the premotor cortex. *Brain*, 119, 593-609.
- Geschwind, N. (1965). Disconnexion syndromes in animals and man. *Brain*, 88, 237-294.
- Ghaziuddin, M. (2008). Defining the behavioral phenotype of Asperger Syndrome. *Journal of Autism and Developmental Disorders*, 38(1), 138-142.
- Ghaziuddin, M., & Butler, E. (1998). Clumsiness in autism and Asperger Syndrome: A further report. *Journal of Intellectual Disability Research*, 42, 43-48.
- Ghaziuddin, M., & Gerstein, L. (1996). Pedantic speaking style differentiates asperger syndrome from high-functioning autism. *Journal of Autism and Developmental Disorders*, 26(6), 585-595.
- Ghaziuddin, M., & Mountain-Kimchi, K. (2004). Defining the intellectual profile of Asperger Syndrome: Comparison with high-functioning autism. *Journal of Autism and Developmental Disorders*, 34(3), 279-284.
- Girolametto, L., Sussman, F., & Weitzman, E. (2007). Using case study methods to investigate the effects of interactive intervention for children with autism spectrum disorders. *Journal of Communication Disorders*, 40(6), 470-492.
- Goldenberg, G. (1995). Imitating gestures and manipulating a mannikin - the representation of the human-body in ideomotor apraxia. *Neuropsychologia*, 33, 63-72.
- Goldenberg, G. (1999). Matching and imitation of hand and finger postures in

- patients with damage in the right or left hemispheres. *Neuropsychologia*, 37, 559-566.
- Goldenberg, G. (2003). Apraxia and beyond: Life and work of Hugo Liepmann. *Cortex*, 39, 509-524.
- Goldenberg, G., & Hagmann, S. (1997). The meaning of meaningless gestures: A study of visuo-imitative apraxia. *Neuropsychologia*, 35, 333-341.
- Goldenberg, G., & Hermsdorfer, J. (2002). Imitation, apraxia, and hemisphere dominance. In: A.N. Meltzoff & W. Prinz (Eds.), *The imitative mind* (pp.341-346). Cambridge: Cambridge University Press.
- Goldenberg, G., & Karnath, H.O. (2006). The neural basis of imitation is body part specific. *The Journal of Neuroscience*, 26(23), 6282-6287.
- Goldenberg, G., & Strauss, S. (2002). Hemisphere asymmetries for imitation of novel gestures. *Neurology*, 59, 893-897.
- Goodglass, H., & Kaplan, E. (1963). Disturbance of gesture and pantomime in aphasia. *Brain*, 86, 703-720.
- Gotham, K., Risi, S., Pickles, A., & Lord, C. (2007). The Autism Diagnostic Observation Schedule: Revised algorithms for improved diagnostic validity. *Journal of Autism and Developmental Disorders*, 37(4), 613-627.
- Griffith, E.M., Pennington, B., Wehner, E., & Rogers, S.J. (1999). Executive functions in young children with autism. *Child Development*, 70, 817-832.
- Gubbay, S.S. (1975). *The clumsy child: A study of developmental apraxic and agnosic ataxia*. London: W. B. Saunders.
- Gunter, H.L., Ghaziuddin, M., & Ellis, H.D. (2002). Asperger Syndrome: Tests of right hemisphere functioning and interhemispheric communication. *Journal of Autism and Developmental Disorders*, 32(4), 263-281.
- Haecaen, H., & Rondot, P. (1985). Apraxia as a disorder of a system of signs. In: E.A. Roy (Ed.) *Neuropsychological studies of apraxia and related disorders* (pp. 75-97). North Holland: Amsterdam.
- Hamilton, A. (2008). Emulation and mimicry for social interaction: A theoretical approach to imitation in autism. *Quarterly Journal of Experimental Psychology*, 61, 101-115.
- Hamilton, A., Brindley, R., & Frith, U. (2007). Imitation and action understanding

in autistic spectrum disorders: How valid is the hypothesis of a deficit in the mirror neuron system? *Neuropsychologia*, 45, 1859-1868.

- Hammes, J.G., & Langdell, T. (1981). Precursors of symbol formation and childhood autism. *Journal of Autism and Developmental Disorders*, 11, 331-346.
- Heath, M., Almeida, Q.J., Roy, E.A., Black, S.E., & Westwood, D. (2003). Selective dysfunction of tool-use: A failure to integrate somatosensation and action. *Neurocase*, 9, 156-163.
- Heilman, K.M., Rothi, L.J.G., & Valenstein, E. (1982). Two forms of ideomotor apraxia. *Neurology*, 32, 342-346.
- Heilman, K.M., & Rothi, L.J.G. (1985). Apraxia. In: K.M. Heilman & E. Valenstein (Eds.), *Clinical neuropsychology* (pp. 131-150). New York: Oxford University Press.
- Heilman, K.M., & Rothi, L.J.G. (1993). Apraxia. In: K.M. Heilman & E. Valenstein (Eds.), *Clinical neuropsychology* (3rd edition: pp. 131-150). New York: Oxford University Press.
- Heilman, K.M., & Rothi, L.G. (1997). Limb apraxia: A look back. In: L.G. Rothi & K.M. Heilman (Eds.), *Apraxia: The neuropsychology of action* (pp.7-16). UK: Psychology Press.
- Heyes, C.M. (2001). Causes and consequences of imitation. *Trends in Cognitive Sciences*, 5, 253-261.
- Hill, E.L. (2004). Evaluating the theory of executive dysfunction in autism. *Developmental Review*, 24(2), 189-233.
- Hill, E.L., & Bird, C.M. (2006). Executive processes in Asperger Syndrome: Patterns of performance in a multiple case series. *Neuropsychologia*, 44(14), 2822-2835.
- Hill, E.L., Bishop, D.V.M., & Nimmo-Smith, I. (1998). Representational gestures in developmental coordination disorder and specific language impairment: Error-types and the reliability of ratings. *Human Movement Science*, 17, 655-678.
- Hill, E.L., & Frith, U. (2003). Understanding autism: Insights from mind and brain. *Philosophical Transactions of the Royal Society Series B*, 358, 281-

- Hobson, R.P. (2002). *The cradle of thought*. London: Macmillan.
- Hobson, J.A., & Hobson, R.P. (2007). Identification: The missing link between joint attention and imitation? *Development and Psychopathology*, 19, 411-431.
- Hobson, R.P., & Lee, J. (1999). Imitation and identification in autism. *Journal of Child Psychology and Psychiatry*, 4, 649-659.
- Hobson, R.P., & Meyer, J.A. (2005). Foundations for self and other: A study in autism. *Developmental Science*, 8(6), 481-491.
- Holden, E.W., Tarnowski, K.J., & Prinz, R.J. (1982). Reliability of neurological soft signs in children: Reevaluation of the PANESS. *Journal of Abnormal Child Psychology*, 10, 163-172.
- Hughes, J.R. (2008). A review of recent reports on autism: 1000 studies published in 2007. *Epilepsy & Behavior*, 13(3), 425-437.
- Jones, V., & Prior, M. (1985). Motor imitation abilities and neurological signs in autistic children. *Journal of Autism and Developmental Disorders*, 15, 37-46.
- Joseph, R.M., Tager-Flusberg, H. & Lord, C. (2002). Cognitive profiles and social-communicative functioning in children with autism. *Journal of Child Psychology and Psychiatry*, 6, 807-821.
- Kanner, L. (1943). Autistic disturbances in affective contact. *Nervous Child*, 2, 217-250.
- Karmiloff-Smith, A., Scerif, G., & Ansari, D. (2003). Double dissociations in developmental disorders? Theoretically misconceived, empirically dubious. *Cortex*, 39, 161-163.
- Kimura, D., & Archibald, Y. (1974). Motor functions of the left hemisphere. *Brain*, 97(1), 337-350.
- Klin, A., Pauls, D., Schultz, R., & Volkmar, F. (2005). Three Diagnostic Approaches to Asperger Syndrome: Implications for Research. *Journal of Autism and*
- Kuschnier, E.S., Bennetto, L., & Yost, K. (2007). Patterns of nonverbal cognitive functioning in young children with autism spectrum disorders. *Journal of*

Autism and Developmental Disorders, 37, 795-807.

- Leighton, J., Bird, G., Charman, T., & Heyes, C. (2008). Weak imitative performance is not due to a functional 'mirroring' deficit in adults with autism spectrum disorders. *Neuropsychologia*, 46, 1041-1049.
- Loh, A., Soman, T., Brian, J., Bryson, S., Roberts, W., Szatmari, P., et al. (2007). Stereotyped motor behaviors associated with autism in high-risk infants: A pilot videotape analysis of a sibling sample. *Journal of Autism and Developmental Disorders*, 37(1), 25-36.
- Lord, C. (2001). *Educating children with autism: Committee on educational interventions for children with autism*. Washington, DC: National Academy Press.
- Lord, C., & Paul, R. (1997). Language and communication. In: D. Cohen & F.R. Volkmar (Eds.), *Handbook of autism and pervasive developmental disorders* (pp. 195-225). New York: Wiley.
- Lord, C., & Risi, S. (2000). Diagnosis of autism spectrum disorders in young children. In: A. M. Wetherby & B.M. Prizant (Eds.), *Autism spectrum disorders: A transactional developmental perspective*. Communication and language intervention series (pp. 11-30). Baltimore, MD: Paul Brookes Publishing.
- Lord, C., Risi, S., & Pickles, A. (2004). Trajectory of language development in autistic spectrum disorders. In: M.L. Rice & S.F. Warren (Eds.), *Developmental language disorders: From phenotypes to etiologies* (pp.7-29). NJ: Erlbaum.
- Lord, C., Rutter, M., DiLavore, P.C., & Risi, S. (2002). *Autism Diagnostic Observation Schedule*. Los Angeles, CA: Western Psychological Services.
- Loveland, K., Tunali-Kotoski, B., Pearson, D., Brelsford, K., Ortegon, J., & Chen, R. (1994). Imitation and expression of facial affect in autism. *Development and Psychopathology*, 6, 433-444.
- Maher, L., & Ochipa, C. (1997). Management and treatment of limb apraxia. In: L.G. Rothi & K. Heilman (Eds.). *Apraxia, neuropsychology of action* (pp. 75-92). East Sussex: Psychology Press.
- Manjiviona, J., & Prior, M. (1995). Comparison of Asperger syndrome and high-

- functioning autistic children on a Test of Motor Impairment. *Journal of Autism and Developmental Disorders*, 25(1), 23-39.
- Mason, R.A., Williams, D.L., Kana, R.K., Minshew, N., & Just, M.A. (2008). Theory of Mind disruption and recruitment of the right hemisphere during narrative comprehension in autism. *Neuropsychologia*, 46(1), 269-280.
- Masur, E.F., & Rodemaker, J.E. (1999). Mothers' and infants' spontaneous vocal, verbal, and action imitation during the second year. *Merrill-Palmer Quarterly*, 45(3), 392-412.
- Mayes, S., Calhoun, S., & Crites, D. (2001). Does DSM-IV Asperger's disorder exist? *Journal of Abnormal Child Psychology*, 29(3), 263-271.
- McDonald, S., Tate, R.L., & Rigby, J. (1994). Error types in ideomotor apraxia: A qualitative analysis. *Brain and Cognition*, 25, 250-270.
- McDonough, L., Stahmer, A., Schreibman, L., & Thompson, S.J. (1997). Deficits, delays, and distractions: An evaluation of symbolic play and memory in children with autism. *Developmental Psychopathology*, 9, 17-41.
- McDuffie, A., Turner, L., Stone, W., Yoder, P., Wolery, M., & Ulman, T. (2007). Developmental correlates of different types of motor imitation in young children with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 37, 401-412.
- Medical Research Council. (2001). *Review of autism research epidemiology and causes*. (pp.1-65). UK: Medical Research Council.
- Meltzoff, A.N. (1988). Infant imitation and memory: Nine-month-olds in immediate and deferred tests. *Child Development*, 59(1), 217-225.
- Meltzoff, A.N. (2002). Elements of a developmental theory of imitation. In: A.N. Meltzoff & W. Prinz (Eds.), *The imitative mind* (pp. 19-42). Cambridge: Cambridge University Press.
- Meltzoff, A.N., & Decety, J. (2003). What imitation tells us about social cognition: A rapprochement between developmental psychology and cognitive neuroscience. *Philosophical Transactions: Biological Sciences*, 358(1431), 491-500.
- Meltzoff, A.N., & Gopnik, A. (1993). The role of imitation in understanding persons and developing a theory of mind. In: S. Baron-Cohen, H. Tager-

- Flusberg & D.J. Cohen (Eds.), *Understanding other minds: Perspectives from autism* (pp. 335-366). New York: Oxford University Press.
- Meltzoff, A.N., & Moore, K.M. (1977). Imitation of facial and manual gestures by human neonates. *Science*, 198, 75-78.
- Meltzoff, A.N., & Moore, K.M. (1983). Newborn infants imitate adult facial gestures. *Child Development*, 54(3), 702-709.
- Meyer, J.A., & Hobson, R.P. (2004). Orientation in relation to self and other: The case of autism. *Interaction Studies*, 5, 221-244.
- Miller, J.N., & Ozonoff, S. (1997). Did Asperger's cases have Asperger Disorder? A research note. *Journal of Child Psychology and Psychiatry, Allied Disciplines*, 38 (2), 247-251.
- Milne, E., Swettenham, J., Hansen, P., Campbell, R., Jeffries, H., & Plaisted, K. (2002). High motion coherence thresholds in children with autism. *Journal of Child Psychology and Psychiatry*, 43, 255-263.
- Minshew, N.J., & Williams, D.L. (2007). The new neurobiology of autism: Cortex, connectivity, and neuronal organization. *Archives of Neurology*, 64(7), 945-950.
- Miyahara, M., & Möbs, I. (1995). Developmental dyspraxia and developmental coordination disorder. *Neuropsychology Review*, 5(4), 245-268.
- Moody, E., & McIntosh, D. (2006). Mimicry and autism: Bases and consequences of rapid, automatic matching behavior. In: S. Rogers & J.H. Williams (Eds.), *Imitation and the social mind* (pp. 71-88). New York: Guilford Press.
- Morgan, S.B., Cutrer, P.S., Coplin, J.W., & Rodrigue, J.R. (1989). Do autistic children differ from retarded and normal children in Piagetian sensorimotor functioning? *Journal of Child Psychology and Psychiatry*, 30, 857-864.
- Morris, M. (1997). Developmental Dyspraxia. In: L.G. Rothi & K. Heilman (Eds.), *Apraxia, the neuropsychology of action* (pp. 245-267). East Sussex: Psychology Press.
- Mostofsky, S.H., Dubey, P., Jerath, V.K., Jansiewicz, E.M., Goldberg, M., & Denckla, M.B. (2006). Developmental dyspraxia is not limited to imitation

- in children with autism spectrum disorders. *Journal of the International Neuropsychological Society*, 12, 314-326.
- Motomura, N., & Yamadori, A. (1994). A case of ideational apraxia with impairment of object use and preservation of object pantomime. *Cortex*, 30, 167-170.
- Mozaz, M., Rothi, L.G., Anderson, L.M., Crucian, G.P., & Heilman, K.M. (2002). Postural knowledge of transitive pantomimes and intransitive gestures. *Journal of International Neuropsychological Society*, 8, 958-962.
- Mundy, P., Sigman, U., & Kasari, C. (1990). A longitudinal study of joint attention and language development in autistic children. *Journal of Autism and Developmental Disorders*, 20(1), 115-128.
- Nadel, J. (2006). Does imitation matter to children with autism? In: S. Rogers and H.G. Williams (Ed.), *Imitation and the social mind* (pp. 118-150). New York: The Guilford Press.
- Nagy, E., & Molnar, P. (2004). Homo imitans or homo provocans? Human imprinting model of neonatal imitation. *Infant Behavior and Development*, 27, 54-63.
- National Autistic Society (2009). Statistics: How many people have autism spectrum disorder? Retrieved on ----(date) from <http://www.nas.org.uk/nas/jsp>.
- National Research Council, Committee on Educational Interventions for Children with Autism (2001). *Educating children with autism*. Washington DC: National Academies Press.
- Oberman, L.M., & Ramachandran, V.M. (2007). The simulating social mind: The role of the mirror neuron system and simulation in the social and communicative deficits of autism spectrum disorders. *Psychological Bulletin*, 133(2), 310-327.
- Ochipa, C., Rothi, L.J.G., & Heilman, K.M. (1989). Ideational apraxia: A deficit in tool selection and use. *Annals of Neurology*, 25, 190-193.
- Ochipa, C., Rothi, L.J.G., & Heilman, K.M. (1992). Conceptual apraxia in Alzheimer's Disease. *Brain*, 115, 1061-1071.
- Ochipa, C., Rothi, L.J.G., & Heilman, K.M. (1994). Conduction apraxia. *Journal*

- of Neurology, Neurosurgery, and Psychiatry*, 57, 1241-1244.
- Ohta, M. (1987). Cognitive disorders of infantile autism: A study employing the WISC, spatial relationship conceptualization and gesture imitations. *Journal of Autism and Developmental Disorders*, 17, 45-62.
- Overton, W.F., & Jackson, J.P. (1973). The representation of imagined objects in action sequences: A developmental study. *Child Development*, 44(2), 309-314.
- Ozonoff, S., Williams, B.J., Gale, S., & Miller, J.N. (1999). Autism and autistic behavior in Joubert Syndrome. *Journal of Child Neurology*, 14(10), 636-641.
- Ozonoff, S., South, M., & Miller, J.N. (2000). DSM-IV defined Asperger Syndrome: Cognitive, behavioural and early history differentiation from high functioning autism. *Autism* 4, 29-46.
- Ozonoff, S., Strayer, P.L., McMahon, W.M., & Filloux, F. (1994). Executive functioning abilities in autism and Tourette Syndrome: An information processing approach. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 35(6), 1015-1032.
- Ozonoff, S., Young, G., Goldring, S., Greiss-Hess, L., Herrera, A., Steele, J., Macari, S., Hepburn, S., & Rogers, S.J. (2008). Gross motor development, movement abnormalities, and early identification of autism. *Journal of Autism and Developmental Disorders*, 37, 354-366.
- Page, J., & Boucher, J. (1998). Motor impairments in children with autistic disorder. *Child Language Teaching and Therapy*, 14(3), 233-259.
- Pazzaglia, M., Smania, N., Corato, E., & Aglioti, S.M. (2008). Neural underpinnings of gesture discrimination in patients with limb apraxia. *Journal of Neuroscience*, 28(12), 3030-3041.
- Pellicano, E. (2007). Links between theory of mind and executive function in young children with autism: Clues to developmental primacy. *Developmental Psychology*, 43(4), 974-990.
- Pennington, B., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry*, 37(1), 51-87.

- Pickering, S. & Gathercole, S. (2001). *The working memory test battery for children*. London: Harcourt.
- Poeck, K. (1986). The clinical examination for motor apraxia. *Neuropsychologia*, 24, 129-134.
- Press, C., Bird, G., Walsh, E., & Heyes, C. (2008). Automatic imitation of intransitive actions. *Brain and Cognition*, 67, 44-50.
- Prizant, B.M., Wetherby, A.M., & Rydell, P.J. (2000). Communication intervention issues for young children with autism spectrum disorders. In: A. M. Wetherby & B.M. Prizant (Eds.), *Autism spectrum disorders: A transactional developmental perspective* (pp. 193-224). Baltimore, MD: Brookes Publishing.
- Rapin, I. (1999). Appropriate investigations for clinical care versus research in children with autism. *Brain Development*, 21(3), 152-156.
- Rajendran, G., & Mitchell, P. (need year). Cognitive theories of autism. *Developmental Review*, 27, 224-260.
- Raymer, A., & Ochipa, C. (1997). Conceptual praxis. In: L.G. Rothi & K. Heilman (Eds). *Apraxia, neuropsychology of action* (pp. 51-58). East Sussex: Psychology Press.
- Ricks, D., & Wing, L. (1975). Language, communication, and the use of symbols in normal autistic children. *Journal of Autism and Childhood Schizophrenia*, 5, 191-221.
- Riddoch, M.J., Humphreys, G.W., & Price, C.J. (1989). Routes to action: Evidence from apraxia. *Cognitive Neuropsychology*, 6(5), 437-454.
- Rinehart, N.J., Bradshaw, J.L., Brereton, A.V., & Tonge, B.J. (2002). A clinical and neurobehavioural review of high-functioning autism and Asperger's disorder. *Australian and New Zealand Journal of Psychiatry*, 36, 762-770.
- Rizzolatti, G., Fadiga L., Gallese, V., & Fogassi, L. (1996a). Premotor cortex and the recognition of motor actions. *Cognitive Brain Research*, 3, 131-141.
- Rizzolatti, G., Fogassi, L., & Gallese, V. (2001). Neurophysiological mechanisms underlying the understanding and imitation of action. *Nature Neuroscience Reviews*, 2(9), 661-670.
- Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annual Review*

of? *Neuroscience*, 27, 169-192.

- Rodrigue, J.R., Morgan, S.B., & Geffken, G.R. (1990). Families of autistic children: Psychosocial functioning of mothers. *Journal of Clinical Child Psychology*, 19, 371-379.
- Roeyers, H., Van Oost, p., & Bothuyne, S. (1998). Immediate imitation and joint attention in young children with autism. *Development and Psychopathology*, 10, 441-450.
- Rogers, S.J., Bennetto, L., McEvoy, R., & Pennington, B. (1996). Imitation and pantomime in high-functioning adolescents with autism spectrum disorder. *Child Development*, 67, 2060-2073.
- Rogers, S.J., Hepburn, S., Stackhouse, T., & Wehner, E. (2003). Imitation performance in toddlers with autism and those with other developmental disorders. *Journal of Child Psychology and Psychiatry*, 44(5), 763-781.
- Rogers, S., & Pennington, B. (1991). A theoretical approach to the deficits in infantile autism. *Development and Psychopathology*, 3, 137-162.
- Rogers, S.J., & Williams, J.H. (2006). Imitation in autism findings and controversies. In: S. Rogers & J.H. Williams (Eds.), *Imitation and the social mind* (277-303). New York: Guilford Press.
- Rogers, S. J., Young, G., Cook, I., Giolzetti, A., & Ozonoff, S. (2008). Deferred and immediate imitation in regressive and early onset autism. *Journal of Child Psychology and Psychiatry*, 49(4), 449-457.
- Rose, M., & Douglas, J. (2003). Limb apraxia, pantomime, and lexical gesture in aphasic speakers: Preliminary findings, *Aphasiology*, 17(5), 453-464.
- Rothi, L.G., & Heilman, K. (1985). Ideomotor apraxia: Gestural learning and memory. In: E.A. Roy (Ed.), *Neuropsychological studies in apraxia and related disorders* (pp.65-74). New York: North Holland.
- Rothi, L.G., & Heilman, K. (1997). Introduction to limb apraxia. In: L.G. Gonzales & K. Heilman (Eds.), *Apraxia, the neuropsychology of action* (pp. 1-6). East Sussex: Psychology Press.
- Rothi, L.G., Mack, L., & Heilman, K. (1986). Pantomime agnosia. *Journal of Neurology, Neurosurgery, and Psychiatry*, 49, 451-454.
- Rothi, L., Ochipa, C., & Heilman, K. (1991). A cognitive neuropsychological

- model of limb praxis. *Cognitive Neuropsychology*, 8, 443-458.
- Rothi, L.G., Ochipa, C., & Heilman, K.M. (1997). A cognitive neuropsychological model of limb praxis and apraxia. In: L.G. Rothi & K. Heilman (Eds.), *Apraxia, the neuropsychology of action* (pp. 29-48). East Sussex: Psychology Press.
- Rothi, L.G., Raymer, A.M., Ochipa, C., Maher, L.M., Greenwald, M.L., & Heilman, K.M. (2003). *Florida Apraxia Battery-Revised*.
- Roy, E.A., Elliott, D., Dewey, D., & Square-Storer, P. (1990). *Impairments to praxis and sequencing in adult and developmental disorders*. (pp. 359-379). Columbia, SC: University of South Carolina Press.
- Roy, E.A., & Square, P.A. (1985). Common considerations in the study of limb, verbal, and oral apraxia. In: E.A. Roy (Ed.) *Neuropsychological studies and related disorders* (pp. 111-162). North Holland: Amsterdam.
- Rumiati, R.I., & Humphreys, G.W. (1998). Recognition by action: Dissociating visual and semantic routes to action in normal observers. *Journal of Experimental Psychology: Human Perception and Performance*, 24(2), 631-647.
- Rumiati, R.I., Weiss, P.H., Tessari, A., Assmus, A., Zilles, K., Herzog, H., et al. (2005). Common and differential neural mechanisms supporting imitation of meaningful and meaningless actions. *Journal of Cognitive Neuroscience*, 17(9), 1420-1431.
- Rumiati, R.I., Zanini, S., Vorano, L., & Shallice, T. (2001). A form of ideational apraxia as a deficit of contention scheduling. *Cognitive Neuropsychology*, 18, 617-642.
- Rutter, M., Bailey, A., & Lord, C. (2003). *SCQ: The social communication questionnaire - Manual*. Los Angeles: Western Psychological Services.
- Rutter, M., Le Couteur, A., & Lord, C. (2003). *ADI-R: The Autism Diagnostic Interview-Revised*. Los Angeles, CA: Western Psychological Services.
- Sanger, T., Chen, D., Delgado, M., Gaebler-Spira, D., Hallett, M., & Mink, J.W. (2006). Definition and classification of negative motor signs in childhood. *Pediatrics*, 118, 2159-2167.
- Seal, B.C., & Bonvillian, J.D. (1997). Sign language and motor functioning in

- students with autistic disorder. *Journal of Autism and Developmental Disorders*, 27(4), 437-466.
- Shallice, T. (1988). *From Neuropsychology to Mental Structure*. Cambridge: Cambridge University Press.
- Shattuck, P.T. (2006). The contribution of diagnostic substitution to the growing administrative prevalence of autism in US special education. *Pediatrics*, 117(4), 1028-1037.
- Sigman, M. & Ungerer, J. (1984). Cognitive and language skills in autistic, mentally retarded, and normal children. *Developmental Psychology*, 20, 293-302.
- Smith, I.M., & Bryson, S. (1994). Imitation and action in autism: A critical review. *Psychological Bulletin*, 116(2), 259-273.
- Smith, I.M., & Bryson, S. (1998). Gesture imitation in autism I: Nonsymbolic postures and sequences. *Cognitive Neuropsychology*, 15, 747-770.
- Smith, I.M., & Bryson, S.E. (2007). Gesture imitation in autism: II. Symbolic gestures and pantomimed object use. *Cognitive Neuropsychology*, 24(7), 679-700.
- Smith, I., Lowe-Pearce, C., & Nichols, S. (2006). Assessment of imitation abilities in autism. In: S. Rogers, & J.H. Williams (Eds.), *Imitation and the social mind* (pp. 377-394). New York: The Guilford Press.
- Stone, W.L., Lemanek, K.L., Fishel, P.T., Fernandez, M., & Altemeier, W. (1990). Play and imitation skills in the diagnosis of autism in young children. *Pediatrics*, 86, 267-272.
- Stone, W., Ousley, O., & Littleford, C. (1997). Motor imitation in young children with autism: What's the object? *Journal of Abnormal Psychology*, 25, 475-485.
- Szatmari, P., Tuff, L., Finlayson, M.A., & Bartolucci, G. (1990). Asperger's Syndrome and autism: Neurocognitive aspects. *Journal of American Academy of Child and Adolescent Psychiatry*, 29, 130-136.
- Tager-Flusberg, H. (2004). Strategies for conducting research on language in autism. *Journal of Autism and Developmental Disorders*, 34(1), 75-80.
- Tessari, A., Canessa, N., Ukmar, M., & Rumiati, R.I. (2007). Neuropsychological

- evidence for a strategic control of multiple routes in imitation. *Brain*, 130(4), 1111-1126.
- Tessari, A., & Rumiati, R. I. (2004). The strategic control of multiple routes in imitation of actions. *Journal of Experimental Psychology: Human Perception and Performance*, 30(6), 1107-1116.
- Toth, K., Munson, J.N., Meltzoff, A., & Dawson, G. (2006). Early predictors of communication development in young children with autism spectrum disorder: Joint attention, imitation, and toy play. *Journal of Autism and Developmental Disorders*, 36(8), 993-1005.
- Twachtman-Cullen, D. (2000). More able children with autism spectrum disorders: Sociocommunicative challenges and guidelines for enhancing abilities. In: A.M. Wetherby & B.M. Prizant (Eds.), *Autism spectrum disorders: A transactional developmental perspective* (pp. 225-249). Baltimore, MD: Brookes Publishing.
- Uzgiris, I.C., & Hunt, J. (1975). *Assessment in infancy*. Chicago: University of Illinois Press.
- Vanvuchelen, M., Roeyers, H., & De Weerd, W. (2007). Nature of motor imitation problems in school-aged males with autism: How congruent are the error types? *Developmental Medicine and Child Neurology*, 49, 6-12.
- Verté, S., Geurts, H., Roeyers, H., Oosterlaan, J., & Sergeant, J. (2006). Executive functioning in children with an autism spectrum disorder: Can we differentiate within the spectrum? *Journal of Autism and Developmental Disorders*, 36(3), 351-372.
- Vivanti, G., Nadig, A., Young, G.S., Ozonoff, S., & Rogers, S.J. (2008). What do children with autism attend to during imitation tasks? *Journal of Experimental Child Psychology*, 101(3), 186-205.
- Volkmar, F.R. (2003). Changing perspectives on ADHD. *American Journal of Psychiatry*, 160(6), 1025-1027.
- Volkmar, F., Klin, A., & Cohen, D.J. (1997). Diagnosis and classification of autism and related conditions: Consensus and issues. In: D. Cohen & F.R. Volkmar (Eds.), *Handbook of autism and pervasive developmental disorders* (pp. 5-40). New York: Wiley.

- Volkmar, F.R., Klin, A., Siegel, B., Szatmari, P., Lord, C., Campbell, M., Freeman, B.J., Cicchetti, D.V., Rutter, M., & Kline, W. (1994). Field trial for autistic disorder in DSM-IV. *American Journal of Psychiatry*, 151, 1361-1367.
- Volkmar, F., & Schwab-Stone, M. (1996). Annotation: Childhood disorders in DSM-IV. *Journal of Child Psychology and Psychiatry*, 37(7), 779-784.
- Volkmar, F.R., State, M., & Klin, A. (2009). Autism and autism spectrum disorders: Diagnostic issues for the future. *Journal of Child Psychology and Psychiatry*, 50(1-2), 108-115.
- Wechsler, D. (1999). *Wechsler abbreviated scale of intelligence (WASI)*. New York: The Psychological Corporation.
- Wetherby, A.M., Prizant, B.M., & Hutchinson, T. (1998). Communicative, social-affective, and symbolic profiles of young children with autism and pervasive developmental disorder. *American Journal of Speech-Language Pathology*, 7, 79-91.
- Wetherby, A.M., Prizant, B.M., & Schuler, A.L. (2000). Understanding the nature of communication and language impairments. In: A. M. Wetherby & B.M. Prizant (Eds.), (pp. 109-134). Baltimore, MD: Brookes Publishing Co.
- Wetherby, A.M., & Prutting, C.A. (1984). Profiles of communicative and cognitive-social abilities in autistic children. *Journal of Speech and Hearing Research*, 27, 364-377.
- Wetherby, A.M., Woods, J., Allen, L., Cleary, Dickinson, H., & Lord, C. (2004). Early indicators of autism spectrum disorders in the second year of life. *Journal of Autism and Developmental Disorders*, 34, 473-493.
- White, S., Frith, U., Milne, E., Rosen, S., Swettenham, J., & Ramus, F. (2006). A double dissociation between sensorimotor impairments and reading disability: A comparison of autistic and dyslexic children. *Cognitive Neuropsychology*, 23(5), 748-761.
- Williams, E., Costall, A., & Reddy, V. (1999). Children with autism experience problems with both objects and people. *Journal of Autism and Developmental Disorders*, 29(5), 367-378.
- Williams, D.L., Goldstein, G., Carpenter, P., & Minshew, N. (2005). Verbal and

- spatial working memory in autism. *Journal of Autism and Developmental Disorders*, 36(6), 747-756.
- Williams, D.L., Goldstein, G., Kojkowski, N., & Minshew, N.J. (2008). Do individuals with high functioning autism have the IQ profile associated with nonverbal learning disability? *Research in Autism Spectrum Disorders*, 2(2), 353-361.
- Williams, D.L., Goldstein, G., & Minshew, N. (2006). The profile of memory function in children with autism. *Neuropsychology*, 20, 21-29.
- Williams, J.H.G., & Waiter, G.D. (2006). Neuroimaging self-other mapping in autism. In: S. Rogers & H.G. Williams (Ed.), *Imitation and the social mind* (pp. 352-372). New York: The Guilford Press.
- Williams, J.H.G., Whiten, A., & Singh, T. (2004). A systematic review of action imitation in autistic spectrum disorder. *Journal of Autism and Developmental Disorders*, 34(3), 285-299.
- Williams, J.H.G., Whiten, A., Suddendorf, T., & Perrett, D. (2001). Imitation, mirror neurons, and autism. *Neuroscience and Biobehavioral Reviews*, 25, 577-596.
- Woodbury-Smith, M., Klin, A., & Volkmar, F. (2005). Asperger's Syndrome: A comparison of clinical diagnoses and those made according to the ICD-10 and DSM-IV. *Journal of Autism and Developmental Disorders*, 35(2), 235-240.
- Woods, J., & Wetherby, A.M. (2003). Early identification of and intervention for infants and toddlers who are at risk for autism spectrum disorder. *Language, Speech, and Hearing Services in the Schools*, 34, 180-193.
- World Health Organization (1994). *Diagnostic criteria for research*. Geneva: World Health Organization.
- Zoia, S., Pelamatti, G., Cuttini, M., Casotto, V., & Scabari, A. (2002). Performance of gesture in children with and without DCD: Effects of input modalities. *Developmental Medicine and Child Neurology*, 44, 699-705.
- Zoia, S., Pelamatti, G., & Rumiati, R.I. (2004). Praxic skills in down and mentally retarded adults: Evidence for multiple action routes. *Brain and Cognition*, 1, 7-17.

Zwaigenbaum, L., Bryson, S., Rogers, T., Roberts, W., Brian, J., & Szatmari, P.
(2005). Behavioral manifestations of autism in the first year of life.
International Journal of Developmental Neuroscience, 23, 143-152.